DOCUMENT RESUME

ED 355 111 SE 053 469

AUTHOR	Rubba, Peter A., Ed.; And Others
TITLE	Excellence in Educating Teachers of Science. The 1993 Yearbook of the Association for the Education of Teachers of Science.
INSTITUTION	Association for the Education of Teachers in Science.; ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, Ohio.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE	Jan 93
CONTRACT	RI88062006
NOTE	302p.
AVAILABLE FROM	ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1929 Kenny Road, Columbus, OH 43210-1015 (Stock No. 507-S, $24.95).
PUB TYPE	Information Analyses - ERIC Clearinghouse Products (071) -- Reports - Descriptive (141) -- Collected Works - General (020)
EDRS PRICE	MF01/PC13 Plus Postage.
DESCRIPTORS	Concept Formation; Educational Change; Educational Research; Education Courses; Education Majors; Elementary Secondary Education; Hearing Impairments; Higher Education; *Inservice Teacher Education; Integrated Curriculum; Learning Theories; Mathematics Education; Methods Courses; *Preservice Teacher Education; Science Curriculum; *Science Education; *Science Teachers; *Teacher Education Curriculum; Teacher Education Programs
IDENTIFIERS	Science Education Research; Science Process Skills

ABSTRACT

This book addresses the question: What is being done to educate current and future teachers of science so that they will be successful in promoting meaningful learning of science? The authors of the 15 chapters in this yearbook explore various dimensions of the preparation and enhancement of teachers of science, including practical and philosophical dimensions. The chapters are: (1) "An Elementary Science Program Emphasizing Teacher's Pedagogical Content Knowledge with a Constructivist Epistemological Rubric (Briscoe, Peters, and O'Brien); (2) "Elementary Science Teacher Education and Integrated Curricula" (Jaeger and Lauritzen); (3) "Integrating Knowledge Bases: An Upper-Elementary Teacher Preparation Program Emphasizing the Teaching of Science" (Krajcik, Blumenfield, Starr, Palincsar, Coppola, and Soloway); (4) "How Teachers Translate Learning Theory into Instruction: A Study of Group Problem Solving by Prospective Secondary Science Teachers" (Tippins, Kagan, and Jackson); (5) "Becoming a Reflective Science Teacher: An Exemplary Endeavor by a Preservice Elementary Teacher" (Roychoudhury, Roth, and Ebbing); (6) "Multicultural Infusion: A Culturally Affirming Strategy for Science Teacher Preparation" (Barba and Bowers); (7) "Reflections on the Role of Teacher Education in Science Curriculum Reform" (Barrow and Tobin); (8) "A Model for Inservice Science Teacher Enhancement through Collaboration of Rural Elementary Schools and Universities" (Prather); (9) "Texas' Science Inservice Programs for Elementary Teachers: 'Stepping' and TESIP" (Lewis and Barufaldi); (10) "The Oregon Consortium for Quality Science and Mathematics Education (OCQSME): Five Years of Collaborative Staff Development (Ault and Ault, Jr.); (11) "'Grow in Science' Explorations in Science, Learning, and Teaching" (Brown and Sinclair); (12) "Placing Gender on the Science Teacher's Agenda: A Program for Professional Development" (Parker); (13) "Creating Cultures for Change in Mathematics and Science Teaching" (Davis, Shaw and McCarty); (14) "A Science Inservice Program Designed for Teachers of Hearing-Impaired Children" (Barman and Shedd); and (15) "Scientific Work Experience Programs for Science Teachers: A Focus on Research-Related Internships" (Gottfried, Brown, Markovits, and Changar). (PR)

ED355111

Excellence in Educating Teachers of Science

Peter A. Rubba • Lois M. Campbell • Thomas M. Dana
Editors

The 1993 Yearbook of the Association for the Education of Teachers in Science

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy

SE

SE 053 469

AETS
The Association for the Education
of Teachers in Science
5040 Haley Center
Auburn University
Auburn, AL 36849-5212

ERIC®
Clearinghouse for Science, Mathematics,
and Environmental Education
1929 Kenny Road
Columbus, OH 43210-1015

BEST COPY AVAILABLE

Excellence in Educating Teachers of Science

Edited by
Peter A. Rubba
Lois M. Campbell
Thomas M. Dana

January 1993

Produced by the

ERIC Clearinghouse for Science, Mathematics
and Environmental Education
1929 Kenny Road
Columbus, OH 43210-1015

PRINTED WITH SOY INK

Cite as:

Rubba, P. A., Campbell, L. M., & Dana, T. M. (Eds.). (1993). *Excellence in educating teachers of science.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Document development:

David L. Haury, *Editor*
Dawn D. Puglisi, *Coordinator*
Linda A. Milbourne, *Copyreader*
Dorothy E. Myers, *U. S. Department of Education Reviewer*
J. Eric Bush, *Cover design and page layout*

This document and related publications are available from ERIC/CSMEE Publications, The Ohio State University, 1200 Chambers Road, Room 310, Columbus, OH 43212. Information on publications and services will be provided upon request.

ERIC/CSMEE invites individuals to submit proposals for monographs and bibliographies relating to issues in science, mathematics, and environmental education. Proposals must include:

- A succinct manuscript proposal of not more than five pages.
- An outline of chapters and major sections.
- A 75-word abstract for use by reviewers for initial screening and rating of proposals.
- A rationale for development of the document, including identification of target audience and the needs served.
- A vita and a writing sample.

This publication was funded by the Office of Educational Research and Improvement, U. S. Department of Education under contract no. RI-88062006. Opinions expressed in this publication do not necessarily reflect the positions or policies of OERI or the Department of Education.

ERIC and ERIC/CSMEE

The *Educational Resources Information Center* (ERIC) is a national information system operated by the Office of Educational Research and Improvement in the U. S. Department of Education. ERIC serves the educational community by collecting and disseminating research findings and other information that can be used to improve educational practice. General information about the ERIC system can be obtained from ACCESS ERIC, 1-800-LET-ERIC.

The ERIC *Clearinghouse for Science, Mathematics, and Environmental Education* (ERIC/CSMEE) is one component in the ERIC system and has resided at The Ohio State University since 1966, the year the ERIC system was established. This and the other 15 ERIC clearinghouses process research reports, journal articles, and related documents for announcement in ERIC's index and abstract bulletins.

Reports and other documents not published in journals are announced in *Resources in Education* (RIE), available in many libraries and by subscription from the Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402. Most documents listed in RIE can be purchased through the ERIC Document Reproduction Service, 1-800-443-ERIC.

Journal articles are announced in *Current Index to Journals in Education* (CIJE). CIJE is also available in many libraries, and can be purchased from Oryx Press, 4041 North Central Avenue, Suite 700, Phoenix, AZ 85012-3399 (1-800-279-ORYX).

The entire ERIC database, including both RIE and CIJE, can be searched electronically online or on CD-ROM.

Online Vendors:	BRS Information Technologies, 1-800-289-4277 DIALOG Information Services, 1-800-334-2564 OCLC (Online Computer Library Center), 1-800-848-5800
CD-ROM Vendors:	DIALOG Information Services, 1-800-334-2564 Silver Platter Information, Inc., 1-800-343-0064

Researchers, practitioners, and scholars in education are invited to submit relevant documents to the ERIC system for possible inclusion in the database. If the ERIC selection criteria are met, the documents will be added to the database and announced in RIE. To submit, send two legible copies of each document and a completed Reproduction Release Form (available from the ERIC Processing and Reference Facility, 301-258-5500, or any ERIC Clearinghouse) to:

ERIC Processing and Reference Facility
Acquisitions Department
1301 Piccard Dr., Suite 300
Rockville, MD 20850-4305

ERIC/CSMEE National Advisory Board

Eddie Anderson, Chief, Elementary and Secondary Programs Branch of the Educational Division, National Aeronautics and Space Administration

Billy Shaw Blankenship, Teacher, Lincoln County High School, Kentucky

David C. Engleson, Former Supervisor, Environmental Education, Wisconsin Department of Public Instruction

James D. Gates, Executive Director, National Council of Teachers of Mathematics

Louis A. Iozzi, Dean, Cook College, Rutgers University

J. David Lockard, Director, The International Clearinghouse for the Advancement of Science Teaching, University of Maryland

E. June McSwain, Environmental Education Consultant, Arlington, Virginia

Phyllis Marcuccio, Assistant Executive Director for Publications, National Science Teachers Association

Senta Raizen, Director, National Center for Improving Science Education

Douglas S. Reynolds, Chief, Bureau of Science Education, New York State Education Department

Thomas Romberg, Director, National Center for Research in Mathematical Sciences Education, University of Wisconsin-Madison

Elgin Schilhab, Mathematics Supervisor, Austin Independent School District, Texas

Gary Sweitzer, Curriculum Consultant, Upper Arlington Public Schools, Ohio

Table of Contents

Foreward viii

Preface ix

Contributing Chapter Authors xvi

Acknowledgements xxiii

Chapter 1 1
An Elementary Science Program Emphasizing Teacher's Pedagogical Content Knowledge Within a Constructivist Epistemological Rubric
Carol Briscoe
Joseph M. Peters
George E. O'Brien

Chapter 2 21
Elementary Science Teacher Education and Integrated Curricula
Michael Jaeger
Carol Lauritzen

Chapter 3 37
Integrating Knowledge Bases: An Upper-Elementary Teacher Preparation Program Emphasizing the Teaching of Science
Joseph S. Krajcik
Phyllis Blumenfeld
Mary L. Starr
Annemarie Palincsar
Brian P. Coppola
Elliot Soloway

Chapter 4 55
How Teachers Translate Learning Theory into Instruction: A Study of Group Problem Solving by Prospective Secondary Science Teachers
Deborah J. Tippins
Dona M. Kagan
David F. Jackson

Chapter 5 69
Becoming a Reflective Science Teacher: An Exemplary Endeavor by a Preservice Elementary Teacher
Anita Roychoudhury
Wolff-Michael Roth
Judy Ebbing

Chapter 6 89
Multicultural Infusion: A Culturally Affirming Strategy for Science Teacher Preparation
Roberrta H. Barba
Rebecca S. Bowers

Chapter 7 115
Reflections on the Role of Teacher Education in Science Curriculum Reform
Dorian Barrow
Kenneth Tobin

Chapter 8 131
A Model for Inservice Science Teacher Enhancement Through Collaboration of Rural Elementary Schools and Universities
J. Preston Prather

Chapter 9 151
Texas' Science Inservice Programs for Elementary Teachers: *Stepping* and TESIP
Melanie C. Lewis
James P. Barufaldi

Chapter 10 177
The Oregon Consortium for Quality Science and Mathematics Education (OCQSME): Five Years of Collaborative Staff Development
Phyllis Campbell Ault
Charles R. Ault, Jr.

Chapter 11 191
Grow in Science: Explorations in Science, Learning, and Teaching
David E. Brown
Marilyn R. Sinclair

Chapter 12 203
Placing Gender on the Science Teacher's Agenda: A Program for Professional Development
Lesley H. Parker

Chapter 13 221
Creating Cultures for Change in Mathematics and Science Teaching
Nancy T. Davis
Kenneth L. Shaw
B. Jo McCarty

Chapter 14 237
A Science Inservice Program Designed for Teachers of Hearing-Impaired Children
Charles R. Barman
Jill D. Shedd

Chapter 15 247
Scientific Work Experience Programs for Science Teachers: A Focus on Research-Related Internships
Sandra S. Gottfried
Christopher W. Brown
Paul S. Markovits
Jerilynn B. Changar

A Brief Guide to ERIC 275

Foreword

As the nation continues its quest for world-class standards in education and increased achievement among students in science and mathematics, the expectation for excellence in science teacher education will spread. World-class standards cannot be achieved without ongoing professional development of world-class teachers, and increased achievement in science and mathematics will not be realized unless teachers are afforded the opportunity to enhance their own skills and knowledge base. This yearbook directly addresses the need for excellence in science teacher education and provides both a theoretical foundation and examples of practices on which we can all build for the future.

The ERIC Clearinghouse for Science, Mathematics, and Environmental Education (ERIC/CSMEE) is pleased to continue its support of yearbooks produced by the Association for the Education of Teachers in Science (AETS). Of the many professional associations in the science education community, AETS is the one devoted specifically to professional development of science teachers. Its members include national leaders in science teacher education and are well qualified to guide our thinking in matters relating to the needs and practices in science teacher preparation and professional development. We at the Clearinghouse thank the contributors and the AETS Publications Committee for their efforts in producing the yearbook and continuing the tradition of collaboration between AETS and ERIC/CSMEE.

The Clearinghouse supports the development of documents like this yearbook in order to facilitate a dialog among practitioners, researchers, policy makers, and other specialists who share an interest in science, mathematics, and environmental education. Readers are encouraged to offer comments on this yearbook and other documents we have produced; we welcome your criticisms, suggestions, and ideas.

David L. Haury, Director
ERIC Clearinghouse for Science, Mathe-matics,
and Environmental Education
1929 Kenny Road
Columbus, OH 43210-1015

Preface

A little more than a half century ago good science teachers were perceived as being born with ability in science, an interest in helping youngsters, and the knack to communicate science knowledge. Science teacher preparation consisted of a liberal arts background, studies in the natural sciences, pedagogical foundations and methods courses, and a practice teaching experience that served mainly to showcase prospective teachers' capabilities.

Following World War II, teacher educators began to seriously study teaching and learning using the quantitative techniques of the natural sciences in an attempt to make learning more efficient and effective. As acceptance of this positivistic perspective took hold and grew in the decades of the '50s and '60s, effective teaching gradually became a technical, behavior-based enterprise. The application of quantitative research methods to teaching and learning resulted in the development of content specific knowledge in areas of education such as science education. Science teacher education became a process of "training" teachers in the faithful use of systematic instructional procedures that were established by research to result in greater learning,.

Today, the education of teachers of science is again in a state of revolution. The legitimacy of the behaviorist and quantitative based view is being questioned and challenged by an emerging paradigm. This is the same cognitive science and qualitative based perspective that has been apparent for years at the cutting edge of science education research, and more recently, in many school science reform efforts.

The educational system is currently embracing numerous efforts to redesign and restructure schools. A central notion in restructuring schools is a definition of learning as an active process in which the learner constructs meaning from experience and prior knowledge. Consequently, science educators are faced with making sense of a new paradigm for teaching and learning of science concepts. Metaphors for teaching science are no longer "teacher as teller" and "teacher as fountain of knowledge." Students do not solely listen and recall. Rather, the teacher is the questioner, guide, coach, and students are inquirers, problems-solvers, and inventors of their own understandings.

It can be argued that the goals of reform in school science education will have been achieved, and the current reform effort judged successful, when ideas in the teaching of science that are currently look upon as innovative become the status quo. By today's practice, most teachers of science will have to do things much differently in their classrooms. As a result, it is both reasonable and timely to ask: What is being done to educate current and future teachers of science so that they will be successful in promoting meaningful learning of science?

Excellence in Educating Teachers of Science, addresses this question in the broadest sense. The authors of the 15 chapters in this 1993 yearbook of the

Association for the Education of Teachers in Science explore various dimensions of the preparation and enhancement of teachers of science, including philosophical and practical dimensions. The chapters offer the reader many insights into the development and effectiveness of some of the latest approaches to the education of teachers of science from teacher preparation programs that feature integrated curricula, to professional practice communities, to research-related internships for science teachers. In addition, timely issues in the education of teachers of science, such as preparing teachers of science to work in multicultural classrooms, enhancing their knowledge, skills and understanding of the significance of gender in teaching science, and the relationship between teacher education and curriculum reform, are examined.

In Chapter 1, "An Elementary Science Program Emphasizing Teachers' Pedagogical Content Knowledge Within A Constructivist Epistemological Rubric, " Carol Briscoe, Joe Peters and George O'Brien describe a four-semester sequence of course work at the University of West Florida in which science content and methods are learned together under a constructivist framework. The focus of the program is on helping preservice elementary teachers develop pedagogical content knowledge in science. Evaluative data collected from preservice teachers who have completed the program indicate that they now find science understandable and feel prepared to teach it.

Michael Jaeger and Carol Lauritzen suggest in Chapter 2, "Elementary Science Teacher Education and the Integrated Curricula," that science teacher educators need to take greater notice of the trend toward curriculum integration, especially at the elementary level. They recommend creating collaborative teacher education faculty teams for curriculum/methods courses in which integrated learning is emphasized. According to the authors, merging teacher preparation courses through interdisciplinary topic, theme, concept, or narrative curricula may provide an ideal context for future teachers to learn the meaning and method of real world problem solving.

In "Integrating Knowledge Bases: An Upper-Elementary Teacher Preparation Program Emphasizing the Teaching of Science," Chapter 3, Joe Krajcik, Phyllis Blumenfeld, Mary Starr, Annemarie Palincsar, Brian Coppola and Elliot Soloway describe the first year of a model teacher preparation program that is focusing on improving the teaching of science in the upper elementary grades. The content of all courses in the program converge around providing elementary preservice teachers with opportunities to develop a strong conceptual base in physical science and a clear understanding of how to teach these concepts to pre- and early-adolescent students. The aim is to enable new teachers to craft and conduct educational experiences designed to deepen students' understanding of fundamental science concepts. An evaluation of some of the programs' strengths and weaknesses, based on the authors' experiences and information collected from students during the first year of its implementation, also is presented.

In Chapter 4, "How Teachers Translate Learning Theory into Instruction: A Study of Group Problem Solving by Prospective Secondary Science Teachers," Deborah Tippins, Dona Kagan and David Jackson report on a study that examined how prospective science teachers understand particular learning theories, not in abstract terms, but in terms of a concrete classroom application. Twenty-four prospective science teachers enrolled in a secondary science teacher education course that used constructivist theory as a referent, worked in groups developing lesson plans. Analysis of transcripts from the group planning lesson revealed some patterns in how the prospective science teachers understood and approached the use of theory in planning. Implications the authors see for connecting theory and practice in science teacher education are discussed.

Anita Roychoudhury, Wolff-Michael Roth and Judy Ebbing argue in Chapter 5, "Becoming a Reflective Science Teacher: An Exemplary Endeavor by a Preservice Elementary Teacher," that more attention needs to be paid to the "artistry" of the profession by incorporating reflection-in-action and on-action into science teacher education practicum experiences. They focus on the reflective experience of Judy, a preservice elementary school teacher. As the study progressed, Judy learned to be a reflective teacher and to act in the indeterminate zones of practice, where situations are uncertain and not bound by the dichotomies of technical rationality. By explicating some of her tacit understandings of small group learning Judy made that knowledge part of her professional expertise. She also became aware of how reflection was beneficial to her as a future teacher. The authors postulate that an extensive practicum that engages student teachers in reflection and deliberation scaffolded by support and guidance may better prepare beginning teachers for excellence in practice.

Robertta Barba and Rebecca Bowers begin Chapter 6, "Multicultural Infusion: A Culturally Affirming Strategy for Science Teacher Preparation," by reminding the reader that nearly every science teacher in this nation will become a teacher in a multicultural classroom within the next decade, but that few preservice science teacher preparation programs are preparing science teachers to work in multicultural classrooms. Using the research, they critique the ethnic studies approach to preparing teachers to work with culturally diverse learners and argue the appropriateness of a multicultural infusion approach. The chapter ends with recommendations on how to infuse culturally affirming strategies into science teacher education.

"Reflections on the Role of Teacher Education in Science Curriculum Reform," Chapter 7, is a report of on-going efforts in the State of Florida to initiate and sustain a systemic reform of science education. In the chapter, Dorian Barrow and Ken Tobin reflect on the relationship between achieving science education reform and science teacher education. Three major, interrelated initiatives are presented as the context to understanding the path of reform in Florida. These include: (a) changes in the content preparation of prospective teachers of science at Florida State University, (b) the enhancement of the professionalism of practicing and prospective teachers at professional practice school sites in Florida, and (c) an effort to implement systemic reform of science education in Florida. Interconnections among the initiatives are discussed, and implications for initiating and sustaining reform efforts in Florida and elsewhere are presented.

In Chapter 8, "A Model for Inservice Teacher Enhancement Through Collaboration of Schools and Universities," Preston Prather identifies some conditions that supported an effort at reforming elementary school science in rural settings. The conditions he identifies involve a cooperative effort between a university, a state department of education, and 27 strategically located rural school systems. A central notion behind Prather's model is continuous growth in leadership and outreach for local reform teams. Twenty-seven four-member teams, composed of two inservice elementary teachers, their building principal, and the supervisor of instruction from a school system, offered more than 330 science education programs that directly served more than 7,800 teachers and principals over a three and one-half year period.

Chapter 9, "Texas' Science Inservice Programs for Elementary Teachers: *Stepping* and TESIP," by Melanie Lewis and Jim Barufaldi, describes two elementary science inservice programs that were developed and disseminated in Texas from 1986 to the present. *Stepping* Into Successful Science Teaching (*Stepping*) focuses on hands-on inquiry and process-based science instruction, and complementary skills such as cooperative group management and question asking. The Texas Elementary Science Inservice Program (TESIP) focuses on development of science concepts using themes from Project 2061 and the 5E instructional model, and provides a model for evaluating hands-on science instruction. Evaluation results from each program are presented.

"The Oregon Consortium for Quality Science and Mathematics Education (OCQSME): Five Years of Collaborative Staff Development," which is described in Chapter 10 by Phillis Ault and Charles Ault, included 12 local school districts, the Oregon Museum of Science and Industry (OMSI), and Lewis & Clark College. Using pooled Eisenhower money, local teachers in leadership roles and guidance from a cross-district team of administrators, the OCQSME implemented a plan for staff development and curriculum innovation (K-12) over a five year period. Included were topics such as, the National Council of Teachers of Mathematics standards, the engineering-based "Design Technology," use of thematic units in elementary education, and coordinated concept development across subject fields in secondary science.

David Brown and Marilyn Sinclair in "*Grow In Science*: Explorations in Science, Learning, and Teaching," Chapter 11, describe a summer course for practicing elementary teachers designed collaboratively by representatives from a school district, a community college, and a research university. This coalition is presented as a model of collaboration that might be fruitfully adopted elsewhere. The teachers were engaged in reflecting on a constructivist perspective on learning in inquiry oriented situations first from the perspective of a learner, and then from the perspective of a teacher, as they worked with children. Analysis of the largely qualitative data sources indicates significant growth in both the teachers' and the children's willingness and ability to engage in fruitful inquiry, and in the teacher's willingness and ability to structure classroom environments to encourage inquiry.

In Chapter 12, "Placing Gender on the Science Teacher's Agenda: A Program for Professional Development," Lesley Parker describes and analyzes the development and evaluation of a science teacher development program focusing on gender issues in science education. Much recent research points to the need to enhance teachers' knowledge, skills and understanding of the significance of gender in their professional practice. The program has a number of distinctive features: (a) it addresses science-related gender issues from a strong international research base; (b) the program delivery style itself exemplifies a gender-inclusive approach; (c) it acknowledges and caters to the needs of teachers as professionals by helping them to make sense of their own professional practice and to help others in this regard; and (d) it is transferable to other situations.

"Creating Cultures for Change," Chapter 13 by Nancy Davis, Kenneth Shaw and B. Jo McCarty, describes a school-based project in which teachers reconceptualize their roles and their students' roles in teaching and learning consistent with a consensual vision. The authors discuss the theoretical basis of transformational change, and the development and evolution of the Enhancement of Mathematics and Science Teaching (EMST) Project, focusing on the first three years of its operation. Volunteer teachers form "families of schools" (elementary, middle and high schools that a group of students would progress through) participated in the project. The authors served as facilitators, guides and researchers. Changes in the teachers as they reconceptualized roles and constraints, and resulting changes in students' roles in learning are discussed.

In "A Science Inservice Program Designed for Teachers of Hearing-Impaired Children," Chapter 14, Charles Barman and Jill Shedd note that teachers of hearing-impaired children generally lack adequate preparation in science education and, therefore, tend to omit this subject from their curriculum. Yet, special educators claim there is no pedagogical reason for omitting science from the deaf child's curriculum and advocate the use of "hands-on" exploratory experiences with hearing-impaired children. This chapter describes the development, implementation, and evaluation of a K-8 science inservice program for teachers of hearing-impaired children in the State of Indiana. The overall goal of this effort was to enhance the science teaching skills of these teachers. Evaluation data obtained during the project are reported and discussed.

Sandra Gottfried, Christopher Brown, Paul Markovits and Jerilynn Changar open Chapter 15, "Scientific Work Experience Programs for Teachers: A Focus on Research-Related Internships," by introducing the reader to and distinguishing among the three types of scientific work experience programs for science teachers that are operating across the U.S.—project internships, research internships, and combination project and research internships. The four internship programs operated separately by the authors in St. Louis are provided as examples. Results from evaluations of these four internship programs are presented which indicate that science teachers make substantial gains in the affective domain, and in areas such as: science content knowledge, scientific research design and experimentation, an understanding of what engineers and scientists do day-to-day, knowledge of applications of science, and the relationship of math and science to technology and society.

Collectively, the authors of these yearbook chapters make the case that the education of teachers of science is a major feature in the science education reform process. In selecting chapters for the yearbook, the editors took the point of view that merely providing descriptions of excellent programs to educate teachers of science is not sufficient to inform and advance practice. Consequently, the reader will find that most authors go beyond description to discuss research associated with program effectiveness.

Since 1974, the Association for the Education of Teachers in Science has sponsored 15 yearbooks that have contributed significantly to theory and practice in the education of teachers of science and science education in general. It is the editors' hope that ***Excellence in Educating Teachers of Science*** follows in that tradition by contributing to the ongoing critical review of science teacher education practice and serving as a resource of ideas for those educators who wish to reconceptualize the process.

P.A.R.
L.M.C.
T.M.D.

THE YEARBOOK EDITORS

Peter A. Rubba
The Pennsylvania State University
165 Chambers Building
University Park, PA 16802
(814) 863-2937
FAX: (814) 863-7602
BITNET: RCD@PSUVM
INTERNET: RCD @PSUVM.PSU.EDU

Lois M. Campbell
The Pennsylvania State University
157 Chambers Building
University Park, PA 16802
(814) 865-6568
FAX: (814) 863-7602
BITNET: LMC7@PSUVM
INTERNET: LMC7@PSUVM.PSU.EDU

Thomas M. Dana
The Pennsylvania State University
160 Chambers Building
University Park, PA 16802
(814) 865-1500
FAX: (814) 863-7602
BITNET: TMD3@PSUVM
INTERNET: TMD3@PSUVM.PSU.EDU

CONTRIBUTING CHAPTER AUTHORS

Charles R. Ault Jr.
Lewis & Clark College
2733 Greentree Road
Lake Oswego, OR 97034

Phyllis Campbell Ault
Independent Consultant
2733 Greentree Road
Lake Oswego, OR 97034

Robertta H. Barba
San Diego State University
CRMSE
6475 Alvarado Road
Suite 206
San Diego, CA 92182-0315

Charles R. Barman
Indiana University
School of Education at Indianapolis
902 West New York Street
Indianapolis, IN 46202-5155

Dorian A. Barrow
Florida State University
203 Carothers Hall
Tallahassee, FL 32306

James P. Barufaldi
The University of Texas at Austin
Science Education Center
EDB-340
Austin, TX 78712

Phyllis Blumenfeld
University of Michigan
School of Education
610 E. University
Ann Arbor, MI 48109-1259

Rebecca S. Bowers
Old Dominion University
Department of Educational Curriculum and Instruction
Darden College of Education
Norfolk, VA 23529-0161

Carol Briscoe
University of West Florida
11000 University Parkway
Pensacola, FL 32514-5753

Christopher W. Brown
Ferguson-Florissant (Missouri) School District
2437 Strawberry Fields Court
Florissant, MO 63033

David E. Brown
University of Illinois at Urbana-Champaign
384 Education Building
1310 S. Sixth Street
Champaign, IL 61820

Jerilynn B. Changar
Southern Illinois University at Edwardsville
7446 Washington
St. Louis, MO 63130

Brian P. Coppola
The University of Michigan
Department of Chemistry
Ann Arbor, MI 48109-1055

Nancy T. Davis
Florida State University—PCC
4750 Collegiate Drive
Panama City, FL 32405

Judy Ebbing
Miami University
1601 Peck Boulevard
Hamilton, OH 45011

Sandra S. Gottfried
University of Missouri—St. Louis
Biology Department
8001 Natural Bridge Road
St. Louis, MO 63121

David F. Jackson
The University of Georgia
Science Education Department
212 Aderhold Hall
Athens, GA 30602-7126

Michael Jaeger
Eastern Oregon State College
1410 "L" Avenue
LaGrande, OR 97850-2899

Dona M. Kagan
George Mason University
10161 Strawflower Lane
Manassas, VA 22110

Joseph S. Krajcik
University of Michigan
School of Education
610 E. University
Ann Arbor, MI 48109-1259

Carol Lauritzen
Eastern Oregon State College
1410 "L" Avenue
LaGrande, OR 97850-2899

Melanie C. Lewis
Southwest Texas State University
Department of Biology
San Marcos, TX 78666

B. Jo McCarty
Florida State University—PCC
4750 Collegiate Drive
Panama City, FL 32405

Paul S. Markovits
Mathematics and Science Education Center
8001 Natural Bridge Road
St. Louis, MO 63121-4499

George E. O'Brien
Florida International University
DM 231 University Park
Miami, FL 33199

Annemarie Palincsar
The University of Michigan
School of Education
610 E. University
Ann Arbor, MI 48109-1259

Lesley H. Parker
c/o SMEC
Curtin University
GPO Box U1987
Perth, West Australia 6001

Joseph M. Peters
University of West Florida
11000 University Parkway
Pensacola, FL 32514-5753

J. Preston Prather
University of Virginia
Curry School of Education
250 Ruffner Hall
Charlottesville, VA 22903-2495

Wolff-Michael Roth
Faculty of Education
Simon Fraser University
Burnaby, BC
Canada V5A 1S6

Anita Roychoudhury
Miami University
1601 Peck Boulevard
Hamilton, OH 45011

Kenneth L. Shaw
Florida State University
4750 Collegiate Drive
Panama City, Fl 32405

Jill D. Shedd
Indiana University
School of Education
201 North Rose Street
Room 4135
Bloomington, IN 47405

Marilyn R. Sinclair
Champaign Unit #4 Schools
Franklin Science Center
817 N. Harris
Champaign, IL 61820

Elliot Soloway
University of Michigan
College of Engineering
1301 Beal Street
Ann Arbor, MI 48109-2122

Mary Starr
University of Michigan
School of Education
610 E. University
Ann Arbor, MI 48109-1259

Deborah J. Tippins
University of Georgia
Science Education Department
212 Aderhold Hall
Athens, GA 30602

Kenneth Tobin
Florida State University
203 Carothers Hall
Tallahassee, FL 32306

ACKNOWLEDGMENTS

The editors recognize Roger G. Olstad, Past AETS President, for commissioning this yearbook. We thank David L. Haury, Director of the ERIC Clearinghouse for Science, Mathematics and Environmental Education and Catherine G. Yeotis, AETS President, for their cooperation during the yearbook's development. We acknowledge the chapter authors for the high quality of their contributions. Lastly, we express deep appreciation to Ms. Stacie Gutschall for the help she provided in preparing manuscripts for inclusion in this yearbook.

P.A.R.
L.M.C.
T.M.D.

To our loved ones:
Sue, Jane and David
John
Nancy

Chapter 1

An Elementary Science Program Emphasizing Teacher's Pedagogical Content Knowledge Within a Constructivist Epistemological Rubric

Carol Briscoe
Joseph M. Peters
George E. O'Brien

Recent national reports have indicated that serious shortcomings abound in our elementary schools with regard to the way science is taught (Carnegie Foundation, 1983; National Commission on Excellence in Education, 1983). Demands upon teachers to teach the basics as well as other social pressures in schools have resulted in an allocation of the majority of instructional time to language arts/reading (64%) and mathematics (17.5%) (Sirotnik, 1988). Furthermore, when science is taught, primary emphasis is placed on talking about science rather than doing science. Stake and Easley (1978) reported that most teachers taught basic facts and definitions from science textbooks, and relatively little emphasis was placed on development of higher-order thinking or problem solving or on the application of science knowledge to everyday events. As Tressel (1988) stated, "for all practical purposes we do not teach any science in elementary schools. One hour a week of so called science doesn't count…" (p. 2).

Historically, curriculum reform efforts have been concentrated on developing elementary school programs that provide teachers with texts and manuals to assist them in developing inquiry-based science programs (i.e. ESS, SAPA, SCIS,). These curriculum materials often come packaged to provide teachers with everything they need to teach science effectively. Yet, studies have shown that the manner in which teachers implement curriculum is often not as the authors intended (Smith & Anderson, 1984). Even when exemplary teachers have used the program, subtle modifications were made in the materials which resulted in altering the program's meaning (Flegg, 1981).

The inability of elementary teachers to implement a curriculum that stimulates their students to become active inquirers into science and creators of meaningful science knowledge may be linked to several factors. These factors include the beliefs the teacher has about science and the nature of science knowledge and the personal epistemology of the teacher (Tobin and Jakubowski, 1990), the quantity and quality of content knowledge in science the teacher has constructed from past experiences in science classes while in school at all levels (Dobey & Schafer, 1984), as well as certain personal characteristics that influence their choices about how much control they are willing to relinquish to students in the teaching/learning environment (Wassermann & Ivany, 1988).

THE CURRENT SITUATION

In a recent survey (Briscoe & Lorsbach, 1990), Florida elementary school principals reported that many of their teachers were unprepared to teach science. They believed that the teachers lacked content knowledge and also noted that many of their teachers lacked confidence in their ability to teach science. Stake and Easley (1978) also noted that teachers in their case studies did not feel confident about their knowledge of science, especially about their understanding of science concepts. They report that these teachers de-emphasized teaching of science and in some cases ignored it completely.

The question raised here then, is how can we better prepare elementary teachers to teach science? The beliefs that teachers possess regarding the nature of science and the nature of science knowledge, as well as their actual knowledge of content in science, are most likely constructed from experiences in school science classes. Many of the beliefs that teachers have about science have been constructed not as a result of direct instruction, but through implicit messages inherent in science texts and science teaching at all school levels. If we expect teachers at the elementary level to implement a curriculum that facilitates students to make inquiries about the natural world independently, to recognize the tentativeness of scientific knowledge, and to develop skills of scientific inquiry and higher-level thinking, we must provide teachers with opportunities to develop those characteristics in themselves first.

Too Much, Too Little

Arons (1980) has condemned the traditional, primarily verbal means by which science knowledge is presented in college courses taken by future elementary teachers noting:

> (L)ecturing at large groups of students who passively expect to absorb ideas that actually demand intense deductive and inductive mental activity coupled with personal observations and experience leaves virtually nothing permanent or significant in the student mind. The procedures that have been found necessary to generate real learning in the elementary school child are equally necessary for the college student. . . college students, despite the words they "know," and the assertions and descriptions they have heard, have no more understanding of ideas involved than a seven-year old approaching the phenomena *de novo*. Purely verbal indoctrination has left essentially no trace of knowledge or understanding (p. 81-82).

Arons contends that traditional courses generally offered over the period of one semester attempt to provide students with an insight into the major achievements of a science. They focus on nothing and "cover" everything from the beginnings of the particular domain to its modern laws and theoretical assumptions. Arons describes the language of such courses as "an incomprehensible stream of technical jargon, not rooted in any experience accessible to the student and presented much too rapidly and in far too high a volume for the assimilation of any significant understanding of ideas, concepts, or theories" (p.82).

Unfeminine Science

Fee (1981) has suggested that very early on, females (who are the primary population from which we draw elementary teachers) construct an understanding of science as a male-dominated field. She notes that Robert J. Lifton, the sociologist, "recently argued that male and female ways of knowing are quite distinct: The males' mode of thought is through abstract ideas and symbols far removed from organic function while the female's pattern of thought is rooted in her identification with organic life and its perpetuation" (p. 85). Fee (1981) asserts that the argument that science is a totally objective and rational way of producing knowledge identifies science as a male way of relating to the world. She continues, "because science as a whole is perceived as male, women in science are perceived as unfeminine" (p. 86).

Lemke (1989) argues that presenting science as a pure, disinterested objective enterprise (which he terms the myth of scientific objectivity) is implicit in the language that is used in teaching science. He asserts that removal of the humanness of everyday language from science talk in classrooms, the elimination of an identification of the creation of science knowledge with people, no mention of specifically human attributes as typical of scientists, and the lack of establishing a relationship between the work of science and human action contribute to an alienation of women from science.

Furthermore, Stake and Easley (1978) reported that sex-role socialization among girls may be the basic factor underlying the sex differences among girls and boys in determining the number of science courses they take in school, as well as their achievement. They reported that girls do not perceive science as useful for future educational and career plans and many lack support from significant others in taking higher-level courses. They cite research by Mary Budd Rowe which indicates that women and minorities who have experienced powerlessness and discrimination tend to believe that they have relatively little control over their own fates, and therefore are less likely to be successful in science, an area in which successful individuals tend to have a stronger sense of fate control.

Clearly, gender issues are a problem that must be dealt with in the design of college courses for individuals who want to become elementary teachers. If prospective teachers, both male and female perceive the nature of science to be an objective, empirical, and rational search for truth about the world, they may pass such views onto the children they teach. Males will continue to benefit from science instruction and females will continue to falter. Because most prospective elementary teachers are women, it is likely that they will continue to believe that they cannot do science and therefore cannot teach science.

THE CONSTRUCTIVIST PERSPECTIVE

Viewing science teaching and learning from a constructivist perspective (von Glasersfeld, 1989), makes clear why many students rarely accomplish meaningful learning in traditional science courses. Constructivists assert that knowledge is uniquely constructed by individuals as sensory data are perceived and interpreted. The nature and extent of the individual's prior knowledge, as well as contextual factors determine the nature of the knowledge that is constructed. Within the constructivist framework, knowledge is perceived as existing within the minds of cognizing beings rather than as an entity that can be transferred directly by sense perception from the natural world or from one individual into the heads of other individuals. Thus, in order for an individual to construct meaningful knowledge she/he must be provided with experiences through which new information can be connected to what is already known. Traditional courses which do not provide experiences that allow connections to be made, foster rote learning and the belief that science knowledge is nothing more than a set of unchanging facts to be learned for the test. It is no wonder that most future elementary teachers enter their science education courses with a distaste for science and little confidence in their ability to learn or teach it.

Implications for Course Design

What implications does constructivism, and the issues related to gender have for the way in which we structure our education programs and science education courses in particular? First, it is apparent that teaching by talking alone does not provide the appropriate context for the construction of much meaningful science knowledge. Although students can construct knowledge from listening, they can only do so if they can relate what is being said to what they already know. In order to facilitate construction then, teachers will have to have an understanding of every student's prior knowledge in order to help each one build upon it, a formidable task if one has several classes.

Even if we are able to diagnose students' prior knowledge, we cannot expect to cover the entire content of several scientific domains within a single semester. The pace of instruction must be slow enough to let students confront the evidence that supports or refutes theories and to re-construct the evidence into meaningful relationships with what they know already. Otherwise, unable to construct meaning, students will simply memorize information and soon forget what they thought they had "learned." Or if they do remember anything, it is bits and pieces that they cannot put together into meaningful statements or insights of their own.

The second implication of constructivism is that teaching and learning are intertwined in a communicative process. What we know about the world is an interpretation based on sense perception and prior knowledge. But how do we know that our perceptions are compatible with others? In the case of science, how do we know that the explanations we have constructed for natural phenomena are the same as those that are accepted by scientists? The answer to this question is that we know because we test our knowledge for "fit" with the natural world, and with one another through our language. Accordingly, an emphasis must be placed on collaboration and consensus building as primary activities in order to facilitate meaningful learning. Science classes in which students work together in groups have been shown to provide students of all abilities opportunity to develop a greater understanding of science concepts (Lazarowitz & Galon, 1990). Group problem-solving activities can be introduced into the curriculum as in-class or out-of-class activities. However, teachers must take caution that the problems they ask students to solve are problems that the students perceive as relevant to themselves; otherwise, students will take them simply as additional tasks to be completed, and meaningful learning will not be an outcome of the activity (Wheatley, 1988).

What tasks might future elementary teachers find meaningful? Studies of college students' ability to perform Piagetian tasks are showing that no more than about 25% of the cross section of college students have developed the capacity for abstract logical reasoning and that up to 50% of the students are still using predominantly concrete patterns of reasoning. The remaining 25% seems to be somewhere in the transition (Arons, 1980). These data suggest that tasks which we assign must be of a concrete, hands-on, problem-solving variety. In order to learn science, students will have to do science.

Need for the History of Science

Kauffman (1980) suggests that introducing the history of science into the science curriculum may be one way of dealing with gender issues and helping students to attain a better understanding of science. Representing science as a human endeavor by including an historical perspective makes the subject less impersonal, less rational, and may make it more favorable to women for whom ways of knowing are more closely tied to emotional aspects of subject matter. Furthermore, it has been suggested that the introduction of history into the course enables one to present science as an imaginative enterprise, not based solely on one method.

Teaching history of science may also place the nature of discoveries in their true perspective, not as isolated and independent events created by great men. The historical perspective allows us to present scientists, not as intellectual giants, but as normal humans with strengths and frailties possessed by others. Through teaching of its history, science can be shown as a process, not just as a product (as it is currently presented in most college texts.)

Accordingly, a science education program designed for elementary school teachers should include within its curriculum, one or more science courses that provide opportunities for students to develop an understanding of the nature of science and science knowledge through concrete experiences. Course content and the history of the various domains of science can be addressed through problem-solving activities that allow students to connect new knowledge to what they already know, in social contexts. Taught in this way, future teachers can develop a greater understanding of the nature of science as a human and social process by which knowledge of a rather tentative nature is constructed. They may become more willing to participate in doing science and in turn facilitate the development of excitement for doing science in their future students as well.

In addition, courses must also provide opportunities for future teachers to relate science content to teaching and construct what Shulman (1986) and others (Ashton, 1990; Cochran, 1991) have described as pedagogical content knowledge (PCK). This knowledge, unique to teachers, is a combining of the teachers' knowledge of teaching with their knowledge of the subject matter. It includes transforming what the teachers know into something which the students can understand.

How can all of these requirements be brought together into a meaningful program that will assist future elementary teachers to become effective science teachers? The purpose of this paper is to describe a program for prospective elementary teachers based on a constructivist perspective of teaching and learning which takes into consideration the needs of future teachers to develop both content knowledge and PCK.

COURSE SEQUENCE AND RATIONALE

At the University of West Florida students enter the teacher education program in their junior year and take four semesters of coursework including student teaching. All students have previously completed a traditional core of undergraduate course requirements including mathematics/science, social science, foreign language, and English/humanities.

Preliminary data from surveys administered to students at the beginning of the science education sequence have indicated that the contributions of the science components toward development of prospective teachers' knowledge of science and science teaching is less than optimal. Students express concern that they lack knowledge of science because these courses emphasized rote memorization of science concepts. Furthermore, students indicate that they are reticent to participate in science education courses and have little desire to teach science even though they feel science instruction is important in elementary schools. As was suggested earlier in this chapter and as exemplified by these students, the typical experience in college science courses has not fostered meaningful learning in science nor the development of favorable attitudes towards science or science teaching among entering elementary education students. Accordingly, the science education component of the teacher education program is designed to assist students to overcome their earlier developed lack of confidence regarding science teaching and learning. Further, it is designed to facilitate students' making connections between science teaching and teaching in general, by focusing on the integrated curriculum as a basis for elementary school teaching and learning. As Koballa and Bethel (1985) assert "the integration of science with other disciplines (eg. language arts, social sciences, fine arts, mathematics) has potential for improving both the quantity and quality of science instruction and learning" (p. 80).

Elementary Science Program	
Semester I Soc/Hist/Phil Found of Education Elem & Early Childhood Instruction Microcomputers and Education Health/P. E. for Elementary Schools Music for Elementary School Teachers Art for Elementary School Teachers Language Skills/Literature in Elem Schools	Semester II Science for Elementary Teachers Mathematics for Elementary Teachers Psychological Foundations Multicultural Education Teaching Reading in Elementary Schools Education Exc Student in Mainstreaming
Semester III Teaching Science in Elem Schools Teaching Mathematics in Elem Schools Language Skills Instruction Social Studies for Elem School Teachers	Semester IV Student Teaching Senior Seminar

Figure 1. The course sequence at the University of West Florida

Semester 1

Upon entering the teacher education program, prospective teachers begin a sequence of course experiences that gradually increase their participation in elementary classrooms as teachers (See Figure 1). During the first semester, the focus is on assisting students to make sense of children's learning and to provide discipline-specific instruction in related content areas that will form a part of the integrated curriculum approach fostered in later methods courses.

The Social, Historical, and Philosophical Foundations of Education and the Elementary and Early Childhood Instruction courses initiate an essential foundation for learning to teach science. The foundations course has as its objectives, the understanding of the school environment, and the beginnings of the development of a self-directed, empowered teacher. Early experiences in classrooms are provided in this course. Students are required to make focused observations of teaching and learning settings in local elementary classrooms. They analyze case studies, keep journals on their observations, and complete argumentative essays in support of self-reflection and personal decision making. Through these activities, students begin to conceptualize teachers as change agents in educational communities and become aware of their potential roles in initiating change especially in traditional school settings. This course is integral to the development of students' reflective decision-making about critical science issues, addressed in the science education component. Through the foundations courses they begin preparation for acting on such questions as "shall I teach in a manner that will maintain the status quo in elementary science" or "do I, as an empowered elementary teacher, make radical changes in how science is currently taught,"

The Elementary and Early Childhood course is where the students learn about developmentally appropriate practice in the classroom. Emphasis is placed on planning and implementing curriculum that focuses on children's interests and facilitating their developmental progress. Piagetian experiences are heavily emphasized in primarily science-related situations. Prospective teachers begin to see the need to provide elementary students opportunities to interact with the environment and make sense of situations. These experiences provide a basis important to future discussions of children's theory building during the science education component.

The remaining five courses are seen as important support courses. Language skills and literature courses incorporate a whole-language approach to science and other content areas. Prospective teachers learn to use children's literature as a basis for building contextual frameworks in which science concepts are embedded. The use of literature to create contexts that give children reasons to explore science through an activity-based program is emphasized in both the language courses and in future science education courses. Art, music, and physical education round out the first semester and provide a knowledge base that can be relied on for future integration into the science curriculum. Finally, the microcomputer course builds basic skills in microcomputer operation and software selection to include an introduction to simulations, hypermedia, spreadsheets, data-bases, and wordprocessing that students later use in creating learning activities for science.

Semester 2

The science component of the teacher education program is initiated in the second semester. A three-hour science course titled Science for Elementary School Teachers is required. A primary goal of this course is to put science in a context that associates it with teaching. The science content of the course varies from term to term because students select the specific topics around which teaching and learning activities are planned. However, topics from earth/space science, biology, environmental, and physical sciences, as well as process skills are always included. Through their experiences in this course prospective teachers begin to reconceptualize their content knowledge and build PCK in science.

Students are taught concept mapping skills and are asked to collaborate in small groups to construct concepts maps related to the topic at the beginning of each class. The initial concept mapping activity involves the students in constructing a map of the concept, science. Following this activity students engage in small group discussion relating to the history and philosophy of science. Early on, students are asked to reflect on their understanding of the nature of scientific investigation and the tentative and theoretical nature of science knowledge. They also experience what it is like to be scientists as they attempt to make sense of Oobleck (Sneider, 1985), a thick mixture of starch and water, which has unusual properties.

The Oobleck activity has a profound affect on changing students' beliefs about the nature of science. Groups of students generate theories regarding the nature of Oobleck, then seek to verify their own theories through research in texts. Students engage in the Oobleck activity with the full expectation that when they've completed their investigation, they will be given the one correct explanation for the characteristics of Oobleck they have observed. Throughout the activity they address instructors with the question, "Why does it do this?" A transition in students' beliefs about science is initiated when they find that a substance as common as Oobleck is not well understood by scientists and its properties are explained by multiple theories.

As the course progresses, faculty model and teach science topics in a manner consistent with constructivism. Concurrently, students also teach small groups of their peers, problem-centered lessons on science concepts which are of interest to them. In preparation for peer teaching, students explore the topic on their own at first, researching the content (concept) and how best to teach it to elementary students through cooperative problem-solving activities. Then, three or four small cooperative learning groups are facilitated by the peer teachers who assume roles as resource persons on the selected topic. The groups meet during class time and members switch as time permits to allow students to experience more than one topic per class period. During the peer teaching activities students are asked to focus on hands-on/minds-on learning and developing their own scientific understandings as well as their peers' understanding. At the conclusion of the peer teaching activities the groups are brought together to participate in whole class discussion to share what was learned.

Students are not assessed on their teaching skills during the peer teaching activities; therefore, many are willing to take risks and plan innovative lessons rather than use ready-made teacher-directed lessons from traditional elementary texts. The students report that, as a result of non-threatening participation in peer teaching activities, they develop a more positive attitude towards science and teaching science, and gain confidence in their ability to learn science. Furthermore, our assessments demonstrate that students begin to acquire the basics of scientific literacy recommended by the American Association for the Advancement of Science (1989a, 1989b). The projects and lessons they develop indicate their increased understanding of the concepts and principles of science and the use of scientific ways of thinking as they approach problem-solving activities with a focus on learning.

Evaluation of students is done in a non-traditional way. The mid-term and final are based on a perspective that assessment should be a means for the student to "show what you know" (Dana, Briscoe, Hook & Lorsbach, 1992; Dana, Lorsbach, Hook & Briscoe, 1990; Kulm & Malcom, 1991). Assessment projects are completed in a creative format versus multiple choice or essay testing. Students are allowed to create games, books, computer programs, videotapes, etc.

to show their understanding of science concepts taught in class. Additionally, the students focus on presenting their knowledge of science concepts in a manner which is accessible to children. Again, the emphasis is on developing PCK in conjunction with learning content.

In addition to the science content course, a mathematics content course also is provided during this semester. Because students are asked to plan their peer teaching lessons with a focus on integrating content areas, the offering of these two courses in conjunction with one another provides opportunities for students to use their knowledge of mathematics to explore the science concepts they teach. Other courses, such as exceptional education, psychological foundations, and multicultural education support the science course and provide basic understandings of the elementary student. This is important in developing the social-psychological framework on which to base pedagogical content knowledge.

Semester 3

In the third semester, the curriculum matches what are traditionally seen as the methods courses in many programs. Science, math, language arts, and social studies methods are provided in a block where integration is fostered through combined practicum experiences including the development of an integrated thematic unit. The science methods course emphasizes further development of PCK among the prospective teachers. First, they are made aware of current practices for elementary science and learn how to enhance and/or change these practices to make science concept development more meaningful for elementary students.

History and philosophy of science is seen as an important component during this phase. Various activities develop an awareness of how the scientific enterprise functions and how the history of science has influenced our cultural heritage. Instructors begin with discussion of the history of science education (Collette & Chiappetta, 1989; Henry, 1947, 1960). Students then complete assigned article reviews. A variety of elementary textbooks are compared to show how science has changed over time.

The nature of science is generally introduced with a topic such as phases of the moon or tides. Students are asked to observe and keep records of the natural phenomenon and work together in small groups to come to an understanding of the topic. This investigative experience generates a great deal of initial discussion and increasing awareness of, not only the topic, but how scientists observe and make predictions about phenomenon. Finally, they realize it may take an entire semester or more of investigation to produce an understanding. This provides an experience for students to actually discover scientific understandings for themselves. The experience is generally commented on by the students in rationales for science teaching, which they write near the end of this semester. Their philosophy of science is fine tuned at this point. The university students begin to see how the course instructors have modeled a constructivist approach and how they too can use this approach in their teaching.

Constructivism and its implications for teaching and learning are discussed in relation to each topic that is part of the course curriculum. The use of literature as a basis for introducing science concepts and providing motivation for students to learn science is re-emphasized as students plan lessons for use in the practica (see model lesson plan in Appendix A). Past reform projects and current gender issues are discussed and specifically related to sociological, epistemological, and cultural theoretical perspectives students have become familiar with in earlier foundations courses.

The effectiveness of PCK development and teacher self-development is assessed through microteaching videotaped experiences (O'Brien & Korth, 1991; Peters, 1990, 1992). Students are encouraged to analyze their own teaching and the personal metaphors they use to make sense of teaching. The degree of control and/or facilitation they exhibit as they teach is interpreted in terms of the metaphors students have identified. A second videotaping, late in the semester, is analyzed and students are able to observe and critique their changes over the period of the semester.

Problem solving is another important component of the methods phase. Problem-centered learning is stressed as students interact with elementary students in the schools. The university faculty stress the need to take lessons that are viewed as problem solving by the textbook publishers and change them into true problem-solving experiences.

Computers are another topic during the methods course. Hypermedia projects are developed by students for use at practicum sites. University students choose their own topics and develop software they can use with elementary students. Microcomputer-based labs are introduced and students are allowed time to develop lessons based on toolware which they can build themselves. Science-based simulations, data-bases, and spreadsheets are also used.

Methods Block

The two-week intense practicum helps to bring together all of the things developed during the semester and leads to the student teaching next term. Students are blocked at one school and one of the methods instructors supervises the students during the first 10 weeks of the course. During this phase, students are asked to make focused observations of children as they engage in learning activities. The primary goal of the prospective teachers is to develop an understanding of how children make sense of what they are doing and what they are asked to learn. Class discussions in the science methods course assist prospective teachers to apply what they have learned about how children construct knowledge as they develop lessons for their thematic unit.

The team of methods instructors meet regularly to discuss the progress of the students and to plan classroom experiences that facilitate students to combine lessons from all content areas in developing an integrated thematic unit. Near the end of the semester, classes are suspended and the students complete a two-week, full time pre-student teaching experience. During this time prospective teachers implement lessons from their thematic unit with small groups of students. Because classes at the university are suspended, the science education faculty has the opportunity to visit the practicum schools and observe students.

Semester 4

The culminating student teaching experience allows students a full semester to try out their new orientation toward science in a non-threatening way. Reflective seminars are held each week so that students can interact with university faculty, district teachers, and each other in a problem solving exchange. The practicum supervisors follow the students throughout to reinforce the problem-centered thematic approach to teaching.

IMPLICATIONS FOR THE FUTURE OF SCIENCE EDUCATION

Focus on Constructivism

Constructivism is a referent for our teaching in university science education courses. Through activities and discussions, we facilitate students' making sense of teaching and learning science from a constructivist perspective (von Glasersfeld,1989). The constructivist learning model (Yager, 1991) is used as a framework for planning and implementing problem-centered activities modeled by instructors in the content course. As they participate in learning activities based on the Constructivist Learning Model, students being to conceptualize science as a process that generates knowledge through collaborative activity. They begin to view themselves as capable of generating knowledge about science concepts, and helping others to do so through problem-centered activities. Prospective teachers' experiences as teachers and learners in the content course provide the framework upon which students build personal theories of teaching and learning. By facilitating the development in our students of an empowered approach to science teaching and learning, we lay the foundations for their making sense of the relationship between theory and practice.

An important consideration in constructivist based teacher education is the need to address students' prior knowledge of teaching and learning, the common sense knowledge they have constructed from years of experience in schools. As Erickson, (1987) asserts:

> We must acknowledge that these novice teachers already enter a teacher education program with a vast array of personal theories about teaching, learning, and the educative process in general. . . . It is these personal theories, then, that must undergo the changes that are entailed in shifting novice teachers from a common-sense perspective on teaching to a pedagogical perspective.

We have found that providing opportunities for students to learn science in a constructivist learning environment is a first step toward changing students' common-sense ideas about teaching and learning. Students are also assisted to reconstruct their knowledge of teaching as they engage in open discussion, argument, explanation, and elaboration of their understanding of constructivism and its implications for teaching and learning. Students negotiate personal meaning for constructivism as a referent for their own practices and are encouraged to construct ideal images of teaching and learning consistent with constructivism. Videotapes are used in the first few weeks and the last few weeks of the semester to present pedagogical exemplars based on constructivism. Prospective teachers see the constructivist perspective, where elementary students construct their own knowledge from their social experiences, modeled by their peers and experienced teachers. Students can then make cognitive comparisons of their own practices and images of practice with those of the experienced teachers in a classroom setting. These videos assist prospective teachers to "see" that ideal images of constructivist teaching they have created in classroom discussions and through peer teaching in the controlled university setting are practical images that can be acted upon in real classrooms. Furthermore reinforcing the videotape experience is the fact that a constructivist perspective is taken by several, though not all, instructors who teach the prospective teachers. This has had a significant impact in the success of our science education course sequence.

Benefits of an Integrated Curriculum in Teacher Preparation

Faculty within the teacher education unit have worked closely to achieve a high degree of integration in the elementary school program. This integration is achieved through collaboration among faculty. As defined by Conoley (1989), collaboration is the "role that a teacher adopts when relating to others." It "implies a joint responsibility and action to accomplish a task" (p. 245). This view of education as an integrated, collaborative process is taken by the 30-member department. It helps facilitate problem solving among faculty and allows for a systematic approach to teacher education. All faculty were involved in program development and determination of the knowledge base for the elementary education program. This initial collaboration has paved the way for specialized cooperative efforts, such as the integration of science and children's literature through whole language teaching in science and language arts courses as previously described. The mathematics and science faculty work together on integrated approaches to problem solving and the use of calculators and manipulatives. The reading faculty and the science faculty collaborate on hypermedia approaches to reading and learning science. The students receive a well-rounded curriculum as is evidenced by the professional education model (see Appendix B). Furthermore, observing collaboration being implemented among the faculty helps the prospective teachers see its future benefits in an elementary school environment.

In conclusion, it is felt that students who have participated in the modeled, constructivist-based, integrated program will then go into the schools and "teach as they were taught" (Richner, 1987). Long term studies of our graduates, to determine the effects of the program are still needed. Students have however, informally spoken to the program's success. They feel comfortable teaching science and include it in everyday learning with the children they teach.

REFERENCES

American Association for the Advancement of Science. (1989a). *Project 2061: Science for all Americans.* Washington, DC: Author.

American Association for the Advancement of Science. (1989b). *Project 2061: Science for all Americans Summary.* Washington, DC: Author.

Arons, A. B. (1980). Using the substance of science to the purpose of liberal learning. *Journal of College Science Teaching, 10*(2), 81-87.

Ashton, P. T. (Ed.). (1990). Pedagogical content knowledge. *Journal of Teacher Education, 41*(3).

Briscoe, C., & Lorsbach, A. (1990). Analysis of surveys of Florida principals regarding preparation of elementary teachers in the areas of mathematics, science, computer technology and geography. A report to the Education Standards Commission, Florida Department of Education.

Burton, V. L. (1977). *Mike Mulligan and his steam shovel.* Boston: Houghton Mifflin.

Carnegie Foundation. (1983). *High school: An agenda for action.* New York: Carnegie Foundation.

Cochran, K. F. (1991, September). Pedagogical content knowledge: Teachers' transformations of subject matter. *Narst News, 33(*3), 7-9.

Collette, A. T., & Chiappetta, E. L. (1989). *Science Instruction in the Middle and Secondary Schools.* Columbus, OH: Merrill Publishing Company.

Conoley, J. C. (1989). Professional communication and collaboration among educators. In M. C. Reynolds (Ed.), *Knowledge Base for the Beginning Teacher* (pp. 245-254). New York: Pergamon Press.

Dana, T., Briscoe, C., Hook, K., & Lorsbach, A. (1992, March). *Students showing what they know: Alternatives to traditional assessment practices.* Paper presented at the Annual conference of the National Science Teachers Association, Boston, MA.

Dana, T., Lorsbach, A., Hook, K., & Briscoe, C. (1990, November). *Letting students show what they know: Making sense of assessment in a new age of science education.* Poster session presented at the American Association for the Advancement of Science Forum for School Science, Washington, DC.

Dobey, D. C., & Schafer, L. E. (1984). The effects of knowledge on elementary science inquiry teaching. *Science Education, 68*(1), 39-52.

Erickson, G. L. (1987, April). *Constructivist epistemology and the professional development of teachers.* Paper presented at the annual meeting of the American Education Research Association, Washington, DC.

Fee, E. (1981). Is feminism a threat to scientific objectivity? *Journal of College Science Teaching, 11*(2), 84-92.

Flegg, J. (1981). *Problems and Possibilities of Science Education.* Institute for Research on Teaching, College of Education, Michigan State University. (ERIC Document Reproduction Service No. ED 205 407)

Henry, N. B. (Ed.). (1947). *The Fourty-Sixth Yearbook of the National Society for the Study of Education: Science education in American schools.* Chicago: University of Chicago Press.

Henry, N. B. (Ed.). (1960). *The Fifty-Ninth Yearbook of the National Society for the Study of Education: Rethinking science education.* Chicago: University of Chicago Press.

Kauffman, G. B. (1980). History in the chemistry curriculum: Pros and cons. *Journal of College Science Teaching, 10*(2), 23-27.

Koballa, T. R., & Bethel, L. J. (1985). Integration of Science with other subjects. In D. Holdzkom & P. B. Lutz (Eds.) *Research within reach: Science education. a research-guided response to the concerns of educators.* Charleston, WV: Appalachia Educational Laboratory, Inc.

Kulm, G., & Malcom, S. (Eds.) (1991). *Science assessment in the service of reform.* Washington, DC: American Association for the Advancement of Science.

Lazarowitz, R., & Galon, M. (1990, April). *Learning biology in a cooperative mode in ninth grade heterogeneous classrooms: Students' achievements by method and gender.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta, GA.

Lemke, J. L. (1989). The language of science teaching. In C. Emihovich (Ed.) *Locating learning: Ethnographic perspectives on classroom research.* New Jersey: Ablex. 216-239.

National Commission on Excellence in Education. (1983). *A nation at risk: the imperative for educational reform.* Washington, DC: US Government Printing Office.

O'Brien, G. E., & Korth, W. W. (1991). Videotaping: A tool for enhancing the teacher's understanding of cognitive science and teacher self-development. *Journal of Science Teacher Education, 2*(4), 90-93.

Peters, J. M. (1990). A study of subject matter knowledge in the teaching of science. *Dissertation Abstracts International, 51,* 3377A. (University Microfilms No. DA 9106779).

Peters, J. M. (1992, March). *Preservice science teachers' use of representations.* Paper presented at the annual meeting of the Association for the Education of Teachers in Science, Boston, MA.

Richner, S. (1987). *Modeling good teaching in liberal arts colleges.* (AILACTE Occasional Paper No. 5). Association of Independent Liberal Arts Colleges for Teacher Education. (ERIC Document Reproduction Service No. ED 283 776)

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Sirotnik, K. A. (1988). What goes on in classrooms? Is this the way we want it? In L. E. Beyer & M. W. Apple, (Eds.), *The curriculum: Problems, politics, and possibilities* (pp. 56-76). Albany, N.Y.: SUNY Press.

Smith E. L., & Anderson, C. W. (1984). Plants as producers: A case study of elementary science teaching. *Journal of Research in Science Teaching, 21*(7), 685-698.

Sneider, C. I. (1985). *Oobleck: What do scientists do*? Berkeley, CA: University of California.

Stake, R. E., & Easley, J. A. (1978). *Case studies in science education. (Vol 2.). Design, overview and general findings.* Report prepared for National Science Foundation Directorate for Science Education Office of Program Integration.

Tobin, K., & Jakubowski, E. (1990, April). *Cognitive processes and teacher change.* Paper presented at the annual meeting of the American Education Research Association, Boston, MA.

Tressel, G. W. (1988, April). *A strategy for improving science education.* Paper Presented at the annual meeting of the American Education Research Association, New Orleans, LA.

von Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. *Synthese, 80*(1), 121-140.

Wassermann, S., & Ivany, J. W. G. (1988). *Teaching elementary science: Who's afraid of spiders*? New York. Harper and Row.

Wheatley, G. (1988). *Problem centered learning.* Tallahassee, FL: Florida State University.

Yager, R. E. (1991). The constructivist learning model. *The Science Teacher, 58*(6), 52-57.

APPENDIX A: Model Lesson Plan

1. Contextual framework for lesson:

Begin to view science as integrated with other areas of the curriculum—as an area to teach because it fits with other things children are learning. In this way science is contextualized, it makes sense to children to learn science concepts because they see them as related to other things they do.

One way to view context is to relate science to the content of children's stories. For example, one children's book that can serve as a context for science lessons is *Mike Mulligan and His Steam Shovel* (Burton, 1977). One third grade teacher used this book as a lead in to a unit on simple machines. The children were asked to solve problems related to moving things from place to place using levers, inclined planes, wheels and pulleys. As part of their social studies unit they studied how machines had influenced the lives of people and made work easier throughout history. A number of mathematics activities were associated with measuring and graphing the work machines the children designed could do.

Another way to view context is through themes related to social studies. For example, one fifth grade teacher used Christopher Columbus' trip to the new world as a theme. The teacher chose literature related to Christopher Columbus voyage to the new world for use in reading. In science, one activity based on sinking and floating was used to help children develop a concept of buoyancy and help them understand that ships could only hold a limited amount of supplies or else they would sink. Children also were involved in a treasure hunt activity through which they developed skills in using a compass and measuring distances in the metric system. Math activities included drawing scale models and then measuring out on the playing field, life size diagrams of the boats Columbus sailed. Language arts activities included children writing "sailors" letters home describing "What I saw in the New World."

When you plan your activities, let your mind wander through your own life experiences, go to the library children's book section and to the reference social studies books in the curriculum library. Any of these activities on your part can assist you to develop a context for teaching your science activities which does not necessarily have to relate directly to science as an isolated subject.

As you describe the context for your science lesson, include a section that describes how the science activities are related to other areas in the curriculum including language arts, reading, social studies, mathematics, and, if possible, art and music. Include any children's literature that you think is appropriate for use with, or as a basis for, the science activity.

2. Concepts to be learned:

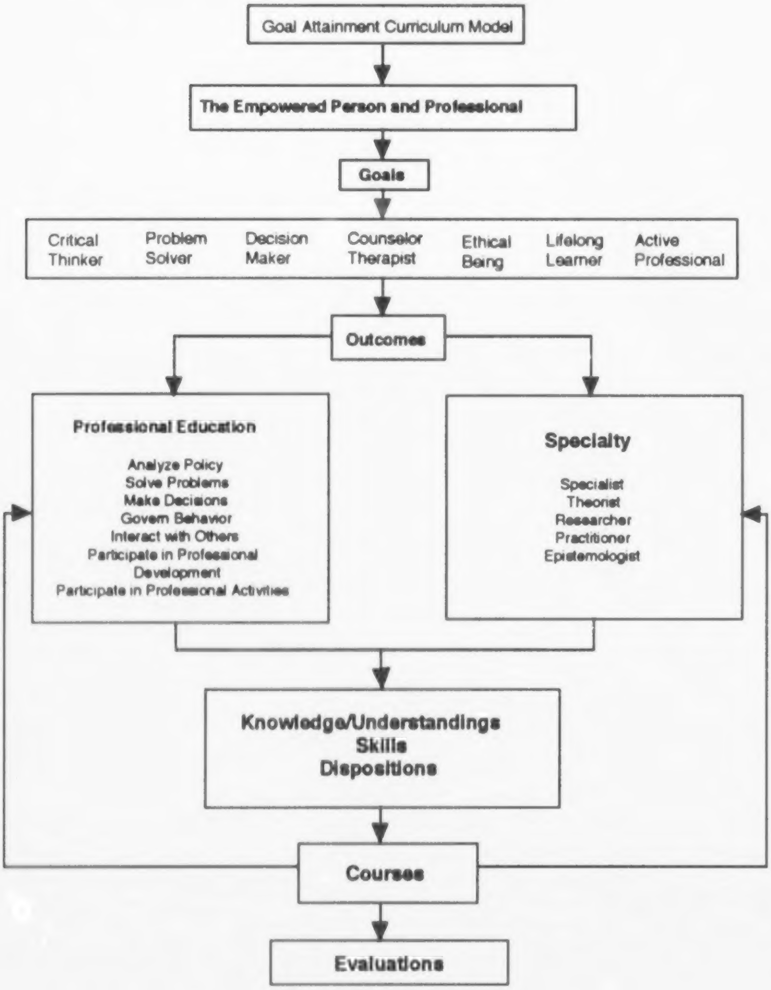
> This section deals directly with the science skills and concepts that you expect children to learn from doing the activities you prepare. Do not write this section as a set of behavioral objectives. Because the way a child behaves does not necessarily demonstrate what has been learned, and because children can learn a great deal without learning specific objectives the teacher had in mind, general statements regarding what might be understood by the children are more appropriate.

Identify two or three content ideas and one or more science process skills that are related to the lesson. In a few sentences describe the major concepts (not facts) and their relationships to science themes (i.e., models, patterns of change, cause and effect, diversity, organization etc.) that you expect the children to learn and what skills you expect them to begin to develop or to improve.

3. Materials:

> **Make a list of all the materials a teacher would need to provide for a group of three or four children to enable them to do the activity.**
>
> This section should not be a specific set of instructions that teacher or children are expected to follow step by step. Children should be involved in a real problem-solving activity and given the opportunity to generate knowledge through their interactions and discussions with one another and with the teacher.
>
> **The following questions should be addressed within the write up for the activity.**
>
> - **What problem will the children be asked to solve?**
> - **How will the materials be presented to the children?**
> - **What choices will the children have regarding how to interact with the materials?**
> - **What are possible actions children might take with the materials?**
> - **How will you interact with the children and the materials?**

Appendix B: UWF Professional Education Model


Goal Attainment Curriculum Model
The Empowered Person and Professional
Goals
Critical Thinker
Problem Solver
Decision Maker
Counselor Therapist
Ethical Being
Lifelong Learner
Active Professional
Outcomes
Professional Education
Analyze Policy
Solve Problems
Make Decisions
Govern Behavior
Interact with Others
Participate in Professional Development
Participate in Professional Activities
Specialty
Specialist
Theorist
Researcher
Practitioner
Epistemologist
Knowledge/Understandings
Skills
Dispositions
Courses
Evaluations

Chapter 2

Elementary Science Teacher Education and Integrated Curricula

Michael Jaeger
Carol Lauritzen

In 1958, Michael's fourth grade teacher, Mrs. Ault, took her class on a six-week tour of Hawaii. Michael remembers the mural of Diamond Head and Waikiki they painted on butcher paper in the back of the room. In the corner there was an outrigger canoe that he pretended to paddle through the surf. Fourth grade noses turned up at the thought of poi but gladly sang the hukilau and did the hula on stage in the big "Hawaii Statehood" extravaganza. Memories remain about stories of Captain Cook getting cooked, about Queen Lili and King Kamehameha, and about all the riches and opportunities that Hawaii would have to offer the Union. With the help of a friend, Michael built a plaster volcano and painted it dark brown with red lava dripping out the caldera. He doesn't remember who the friend was, but he can remember the volcano. What Mrs. Ault had done, of course, was to teach the traditional subjects of social studies, art, music, science, and language arts in an integrated way.

Nearly a half-century later, approaches such as Mrs. Ault's are being revisited and elaborated in the midst of a flurry of curriculum reform activity. State education departments, colleges of education, school districts and individual teachers are studying the potential of integrated curricula while searching for new-century solutions to address current trends (Benjamin, 1989). Workshops, inservices, and college courses are being offered to explore ways in which curricular areas may be meshed. Suddenly, fusing subjects that, for decades, have been separated by time and textbooks is an urgent priority. Science educators ought to take careful notice of this trend toward integration. There are several important reasons for this scrutiny, both philosophic and pragmatic.

PHILOSOPHIC RATIONALE FOR CURRICULUM INTEGRATION

The disciplines approach to education is philosophically rooted in a century old plan for higher education. The idea of separate studies was invented as a way to discipline the mind and to massage certain sensitive areas of the brain especially tuned to each subject. Present paradigms for secondary and elementary education are distillations of this approach leading to a curriculum divided into separate subjects, taught from separate textbooks, and based on separate sets of lesson plans. Each subject is pigeon-holed into its own time and space. Students soon learn that they work word problems in mathematics, read stories in language arts, do experiments in science, draw or paint in art, and play during recess.

Our planet, however, is affected by problems and issues that are not confined to single disciplines. Ecological, technological, social and economic problems are by their very nature multidisciplinary. For example, the old growth forest and spotted owl controversy in Oregon poses a significant scientific problem within a social and economic context. Emerging technologies, historical perspectives, aesthetic understandings, and communication skills are essentials for individuals engaged in solving this type of dilemma. Curriculum for the twenty-first century needs to provide opportunities for students to invent and re-invent solutions to problems so that they may become good problem solvers. School experiences must be integrated across disciplines to reflect the transdisciplinary nature of real life problem solving (Shymansky & Kyle, 1991). Context and meaning are critical aspects of the integrated curriculum (Jaeger & Lauritzen, 1992). In observing a typical elementary classroom, we might see Egypt and the pyramids studied during social studies, simple machines in science, ratios in mathematics, writing directions during language arts, and drawing perspective for art. Yet, children in this classroom may never connect the ideas from one area of study to another. If they learn about the pyramids without experimenting with bricks and inclined planes, pulleys, and levers; without applying mathematical concepts of measurement, ratios, scale and proportion to the pyramid's construction; without exploring, sketching, and forming the structure; without reading, writing, speaking, and listening about the lives of peoples that constructed the pyramids, they may fail to realize the significance of any of this information because the power of context in learning has been neglected. The context is a whole onto which learners can affix specifics. It is a central core that helps arrange and give meaning to learning.

Science educators have embraced at least part of this paradigm of integration by recognizing the important links between science, technology, and society. Integration between theoretical, applied and social sciences has already contributed to forming curriculum that is meaningful and relevant to student's lives. Science, Technology, and Society (STS) curricula demonstrate efforts to link science facts and theories with applications, values, and decisions. This kind of integrated curriculum provides a way for teachers to create a meaningful context for learning—to avoid the "flat" "unconnectedness" that Goodlad (1984) found in schools (Jensen, 1989).

PRAGMATIC REASONS FOR INTEGRATION IN TEACHER EDUCATION PROGRAMS

Integration is also necessary for practical reasons. In a curriculum defined by subject areas, it is very difficult to incorporate required topics sensibly into a unified plan. The school day becomes a fragmented and hurried place (Vann, 1988). The same problem is evident in teacher education programs.

Elementary teacher education is changing. Programs that formerly offered large cores of course work focusing on philosophy, theory, pedagogy, methods, and practice have been modified to emphasize liberal arts preparation (Chronicle of Higher Education, 1989). Methods courses are often sacrificed in the paradigm shift, which favors more academic preparation for future teachers. Education programs have become more compact and transportable and are often designed to serve non-traditional audiences. One-year, post-graduate programs exemplify this compression by requiring field practice, core course work, and methods in the same short time frame. In these programs, elementary curriculum methods courses shrink from three or more semester hours to one or less.

Instructors faced with a paucity of course credits must make hard decisions about what to teach and what to omit. While instructors are pressed to deliver as much as possible in a short time, students are equally stressed to respond by complying with each seminar's demands. The language arts professor requires literature-based reading and writing lessons, the social studies professor requires a unit plan, the science educator wants a series of activities, the fine arts mentor a project and so on. Students try to appease the demands of each course by researching content strands, producing sets of lesson plans, and reciting separate curricular goals and objectives. They frantically try to learn each discipline's pedagogy and often find the experience to be conflicting in some ways and repetitious in others. The need to use time resources more efficiently is a pragmatic rationale to support an integrated approach to teaching science and other methods in pre-service teacher education programs. One way of approaching both philosophic and pragmatic reasons for curriculum integration is to examine integrated models available for elementary curriculum and explore their applicability to pre-service teacher education.

OVERVIEW OF INTEGRATION STRATEGIES

Numerous models have been formulated to integrate curriculum (Chaille & Britian, 1991; Fogarty, 1991; Gamberg, Kwak, Hutchings & Altheim, 1988; Pappas, Kiefer & Levstik, 1990; Shoemaker, 1991;). Each model attempts to create a meaningful context for learning and a vehicle for planning curriculum. These models can be synthesized in various ways. We find examining them in terms of their organizing framework most accessible.

In examining each model, the theoretical framework will be discussed, an example unit will be sketched, and a summary drawn indicating some of the advantages and disadvantages of each design. From these four basic descriptions we generate discussion about how elementary teacher education can accommodate this shift in curricular focus and how methods instructors can begin to incorporate alternative strategies in program delivery.

Topic Integration

Mrs. Ault taught us a topic unit on Hawaii. She had collected stories, resource books, poems, songs, memorabilia, maps, films, readings, pictures and activities that somehow fit with the strand "Hawaii." Some authors suggest that anything can serve as a focus for a topical unit (Reuter, 1989). Most teachers select an area that interests them personally or will appeal to their students. Bears, cats, whales, penguins, dinosaurs, armadillos, seasons, states, kites, popcorn, and apples are common topics. Once the core topic is selected, a web diagram is brainstormed by examining the connection of the topic to the traditional subject areas (See Figure 1). We have done this activity with several groups of teachers with a rather atypical topic, "octopi," to demonstrate how easy it is to develop a topic based unit. By asking "What could we teach related to octopi in the area of (name the discipline)?" and brainstorming answers, teachers created the following:

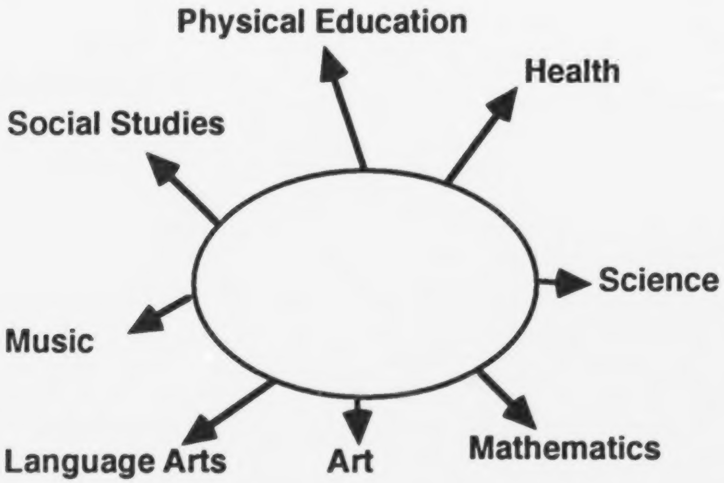


Figure 1. Topic integration.

- Science: Anatomy, biology, ecology and classification of mollusca; biological and medical importance of the octopus eye; physics of jet propulsion and pneumatic suction.
- Social studies: Peoples and places that use the octopi for food or as a tool; geographic distribution of octopi; octopi communities compared to human communities.

- Language arts: Legend and lore versus fact; literature such as *20,000 Leagues Under the Sea* by Verne; *Toilers of the Deep* by Hugo, and *Cannery Row* by Steinbeck; poetry that has eight lines or beats; spelling and defining 'oct' prefix words.

- Physical education: Eight person relays, octopus run, dramatic representation of octopi motion.

- Health: Nutritional value of eating octopi.

- Mathematics: Measurement and size comparisons, the multiplication tables (8's), fractions (eighths), base eight, polygons.

- Art: Water painting with natural dyes and inks, drawing, symmetry, paper models

- Music: Music from the sea, octaves, eight beat rhythm.

After brainstorming, activities and resources are developed and assembled that create a packaged curriculum focusing on octopi while teaching across all eight disciplines.

Topical units are relatively easy to design and teach. Although many published units are available, most teachers develop their own units through resource and activity accumulation. Teachers often spend considerable time and effort preparing a unit of instruction. Kovalik (Kovalik & Olsen, 1986) describes how she spent months finding records, books, activities, and even green plastic strips in garbage dumpsters to make a unit on the jungle. Topical units are often open-ended, offering students opportunities to extend and explore connected areas of interest.

Integration around a topic focus can be problematic, however. Most salient of the dilemmas is the issue of meaningful context. Organizing the curriculum around a topic is somewhat like planning a menu based on the color orange. Dinner will be carrots, orange juice, cheddar cheese and Cheetos! All these items fit the topic but do not create a nutritious meal. This unnatural organization lends itself to what we term "crowbarring," forcing the topic into a discipline even if no meaningful connection exists. For example, in the octopus unit that we generated there was a concerted effort to find art, science, math, music, etc., in the topic. While it was easy to generate content strands and activities in some areas, finding natural adjuncts for others was more difficult. The mathematics activities in the octopus were very much "crowbarred" into the unit and were selected only because they have 'eight' as an element in common.

Topical units often are not so much integrated as they are correlated. They focus on the "trivial" as a justification to tie otherwise unrelated activities together. "They do not achieve the goal of helping children to perceive their world as a dynamic set of interconnections" (Johnson and Louis, 1989). Although a unit should incorporate broad goals, skills, and common culture, this design affords little formal recognition of such requirements. "Such a unit is not designed to develop important concepts and provide opportunities for transfer of skills" (Routman, 1991, p. 277).

If these problems are overcome, topical units can be effective curriculum tools. By carefully selecting non-trivial topics such as the American Revolution, transportation, or rain forests and confining the unit to naturally occurring discipline links, teachers and students can benefit from this form of integration.

A note of clarification seems important here. The term thematic unit is often used to label what we have just described. However, we would distinguish themes from topics. Topics are simply literal labels, something like the entry words in an encyclopedia. Themes, on the other hand, are statements of "big ideas" that are intellectually rich and allow children to examine how the world is interrelated. Shoemaker (1991) includes themes and concepts such as communities, change, power, interactions, form, and systems in the same list. Therefore, we include theme in the following framework for integration.

Concept/Theme Integration

Concepts and themes, unlike topics, are broad ideas and relationships. Systems, cycles, interaction, cause and effect, energy, forces, power, theories, and equilibrium are examples of big ideas that can be used as organizers for integrated curriculum (Oregon State Department of Education, 1989). A concept is not specific to a discipline nor can it be truly understood as a broad concept unless discovered through a set of diverse contexts. For example, the concept of interaction can be found in all subject areas. Biological, social, economic, political, linguistic, artistic, dramatic, and physical systems offer contexts for describing how molecules, people, money, words, actions, or forces interact.

Science concepts and other broad organizers like justice, economy, conflict, equality, diversity, and equilibrium communicate more than a discipline–centered idea. Concepts in this sense are broad ways in which people or conditions are arranged. While concepts can often be captured by one-word labels, themes must be stated in a phrase or sentence. Examples of themes include: How are modern times rooted in the middle ages, prejudice is a destructive social phenomenon, and essentials for survival.

Concept/theme units start with a core idea or relationship that can be examined in several different contexts (see Figure 2). When planning a concept-based unit such as one on interaction, first contexts are selected that embody a mutually reactive relationship. Activities are selected to provide crisp examples of interactions. We can learn about how copper chloride interacts with aluminum foil (science); how the president, legislature, and courts interact (social studies); how characters interact in a story (language arts); how players interact in a game (physical education); how harmonics are created (music); and how our bodies interact with the air we breathe, the water we drink and the food we eat (health).

Children are carefully directed through these contexts to discover the concept, its universality, and its applicability to their lives.

A commercially available program that exemplifies concept integration within the sciences is the Science Curriculum Improvement Study (Thier, Karplus, Lawson, Knott & Montgomery, 1988). Broad organizing concepts are selected to represent the key ideas in science. In the level six models unit, for example, students develop hypotheses about how electrical, magnetic, dynamics and light systems operate. The focus of the unit is not on the details, vocabulary, applications or content of electricity, magnetism, motion, or color, but on the way scientists develop theories to describe nature.

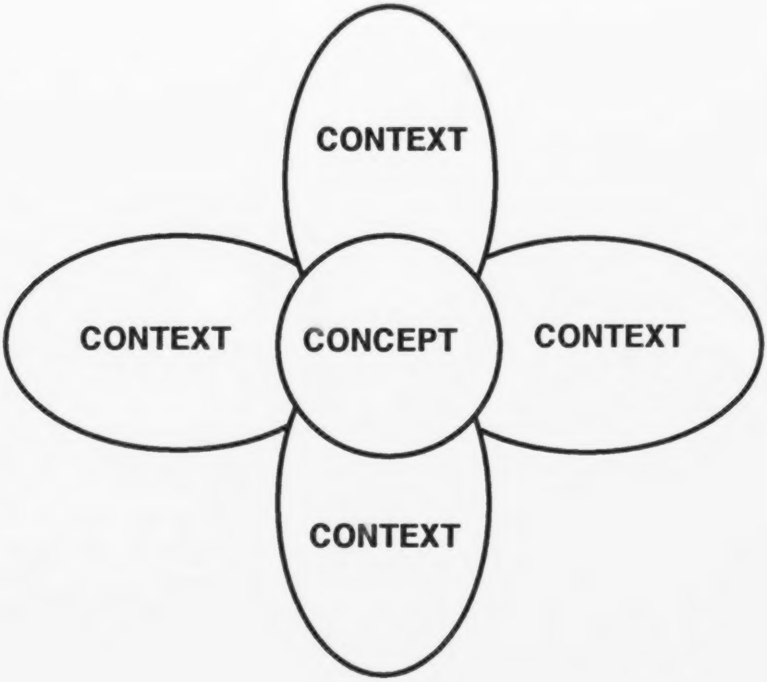


Figure 2. Concept/Theme Integration

Difficulties abound in this form of integration. Textbooks are not arranged by concepts, but rather are typically separated into traditional topics. In order to find a concept in each of the disciplines a teacher must truly understand the concept and be conversant enough in each discipline to recognize embedded concepts.

Teachers have a difficult time embracing concepts as a way to organize curriculum. Although some concepts such as cycle, change, cause and effect, and interaction are fairly easy to identify and develop, other concepts like fundamental entities, gradients, scale, order, power, invariance, model, and replication are more ethereal. Teacher reluctance in adopting concept organization is characterized by one teacher's comment during a course on curriculum theory. He had heard of astronomers, physicists, engineers, and chemists, but had never heard of anybody getting a degree in fundamental entities! Concepts are difficult to warm to, to take ownership of, and to offer to students.

Students often find more interest in the individual topics that serve the concept than in the concept itself. One student that we know who was involved in a unit on cycles typifies this dilemma. Although the unit goals clearly addressed the concept of cycle, the student came away only with facts about invertebrates. The concept was either too lofty or elusive, or the instruction did not actually address the stated goals.

Process Integration

Like topics or concepts, processes (especially processes identified by the sciences) can be organizers for integrated curriculum. Observing, inferring, predicting, experimenting, hypothesizing, calculating, and communicating are action terms describing process skills. Processes become the focus of units and are the framework for the development of activities (see Figure 3).

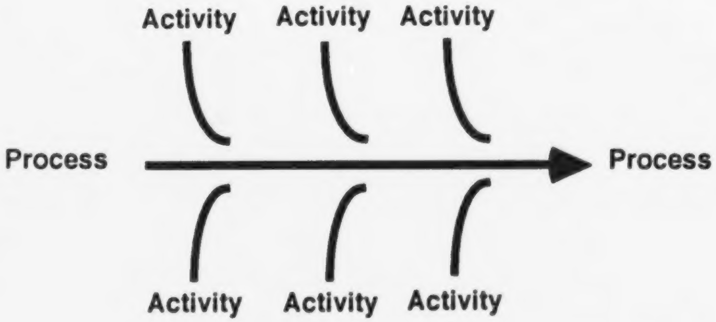


Figure 3. Process Integration

A typical process unit may focus on a skill such as inferring. Activities are aligned to give students several kinds of practice differentiating observation from inference. The first activity might be observing a picture of a forest and looking for clues of animals. After describing what was observed, the students make inferences about what events occurred. During language arts, students gain additional practice in observing and inferring by examining how the author develops story characters. Using descriptions, actions, and words found in the story, the students try to infer character traits. Students can infer about the economy and politics of a foreign country by reading or viewing a videotape about the daily life of the people. They can make inferences about healthy lifestyles from statistics about the exercise, diet, and illness.

Another example of process-based integration is found in a commercial unit on graphing (Matson, 1977). Twenty activities have students measure leaves, stretch rubber bands, draw with mirrors, extrapolate curves, predict population growth, and plot geometric designs. The only thread connecting the activities is that they all use graphing.

Similar to topic units, process units often are not so much integrated as they are correlated. Organizing a curriculum around a process is like planning a menu to provide practice in chewing. Dinner might include beef jerky, celery, boiled squid, and gum! Our jaws get exercised, but our nutritional needs are not met.

This disadvantage can be addressed by providing issues, problems, and projects as a meaningful context for learning process skills. Issues units such as chemical wastes (CEPUP, 1990), health concerns (Pottenger, 1990), and environmental awareness (Bank Street College Project, 1985), offer students opportunity to explore, predict, experiment, interpret while at the same time achieving the broader goals of education. Students become active participants in solving important problems. Born and Jablon (1990) embrace this style of integration and punctuate the effectiveness of using issues as focal points for curriculum: "By involving students from day one in a personal participatory activity that is linked to the academic, social, or technological information to be learned, you can answer the emotional needs of the learners while showing them a way in which to utilize their class work in achieving a goal" (p. 15). Curriculum integration mushrooms from this type of inquiry. Science questions are addressed, social issues are broached with questions about control and aegis, health concerns are important rationale, and anesthetics are of particular interest in the presentation of media and in communication of results. Language arts become the tool for recording and communicating the investigation.

Narrative Integration

A relatively unexplored form for integrating the curriculum can be classified as narrative-based. In this model, stories provide the focus for curriculum organization. A powerful story communicates knowledge, coherence, and comprehension of the human experience. Due to its life-like structure of characters who seek resolution to conflicts, the narrative form provides the greatest opportunity for children to make meaning of their own lives. Stories ring resounding chords of life—captivating us with their events and personalities, providing a springboard for thinking about ourselves and others.

As an integrator of curriculum, the story provides both a starting point and a context that can be revisited as the unit of instruction is formed. At least four types of narratives can be utilized for developing an integrated curriculum: (a) stories from children's literature, (b) historical stories, (c) contemporary stories from the media, and (d) stories generated collaboratively with students. Each of these story forms can provide a framework for developing curriculum.

Consider the children's book, *The Very First Last Time* (Andrews, 1985). The story tells of Eva, a young Inuit girl who walks at low tide under the ice of Ungava Bay in northern Canada. The story is rich with detail about her fears and experiences in the strange icy underworld that is both beautiful and terrible, for the cold, darkness and in-rushing tide present many dangers. The plot and characters are engaging and the pictures are replete with detail of the environment and life of the Inuit. The drama and personalities of this story not only captivate us but lead us to much more. By recognizing the important knowledge, concepts, and relationships embedded in this story, a unit can be developed by asking questions such as: Why is it so cold? Why is the sky different colors? Why are there tides under the ice? What season is it? What kinds of things live under the ice? Where do these people live? What language do they speak? What do they eat? How do they live? Why do the children hunt for food? Why does Eva go under the ice by herself? Is it a sign of adulthood? What are the strange markings on the rocks? What do mussels taste like?

Questions generated by children and careful questions offered by the teacher guide exploration of important concepts embedded in the story. For example, *The Very Last First Time* embodies powerful images of biological, social, physical, and technological systems. Naive perceptions about Inuit life and the Arctic can be explored though activities and research. Prepared for possibilities, the instructor can respond to students' questions and assertions by designing lessons and activities that help children confront their perceptions and construct new knowledge. Children's understanding of how tides, seasons, littoral zones, transportation, and Inuit societies work is developed as they actively seek and demonstrate solutions to questions generated from the text (see Figure 4). Broad goals, skills development, and content are essential issues in planning such a unit.

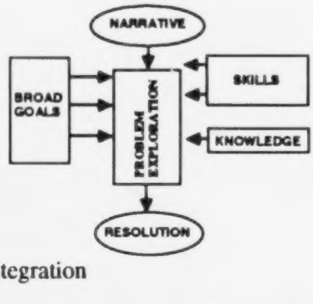


Figure 4. Narrative Integration

Critical to narrative integration is the selection of an appropriate story. While stories from other sources can be used, well-written children's literature is a primary source. These stories are honored for their literary value. Well-written literature insures authentic characters, compelling themes, and worthwhile concepts. It guards against spending time and energy on trivial topics of little relevance in daily life or applicability to more global issues. As is the case with The *Very Last First Time*, a book should be chosen first because it is a compelling story with a worthwhile theme and then because of its curriculum possibilities. We need to be careful to respect literature as a work of art and not merely as a vehicle for instruction.

An advantage of narrative integration is that the story context provides both an anticipatory set and a logical closure for the unit. In a narrative-based curriculum, questions and problems arising from the story offer situations where the knowledge, skills, concepts and processes must be learned in order to seek resolution. In this framework traditional content, or "stuff," has a place but it is relegated to a subordinate role. Facts and knowledge serve the problem generated from interacting with the story and are introduced only to help bring more informed solutions to these problems. This inversion of the curriculum is a radical departure from typical textbook curriculum. One challenge for teachers in adopting a narrative approach is to de–emphasize the facts of the curriculum and to allow traditional "stuff" organization to take a backseat to problem-solving and higher-order thinking skills.

Blending Models

These four models have been presented in an unembellished form. Many possibilities exist for blending. For example, topic and concept integration can be combined. The topic water can be explored as a system, as a cycle, as a fundamental entity, by the forces and energies it generates and the gradients found within it. Process and topic are merged into commercially popular units such as the topic of bubbles focusing on the process of controlling variables (Barber, 1987), bubblegum and designing experiments (Johnson, 1991), radishes and data collection (Matson, 1986), bones and hand skills (Elementary Science Study, 1968), and magnifiers and observation (Sneider, 1988). Other frameworks for integration could be invented as well.

Whatever framework is selected should be evaluated to determine if it meets the broad goals of education, promotes the acquisition of lifelong learning skills, and aids in the assimilation of knowledge. To suffer our metaphor one last time, the menu should be selected to be nutritionally sound, pleasing to the eye and palate, economically feasible, and within the cook's ability to prepare the meal!

APPLICATIONS TO TEACHER EDUCATION

The previous frameworks were for integrating the elementary curriculum but the same rationale, guidelines and levels of involvement apply to teacher education as well. How should science teacher educators proceed with preparing the new-century elementary teacher? What is the role of the science methods instructor? What alternatives are there for teacher educators interested in working to change the way we prepare our elementary teachers? Two issues for contemplation are suggested as requisites for overhauling pre-service curriculum instruction: (a) Faculty in each discipline must work interactively, collaboratively, and sympathetically as interactive teams and must model integration for future teachers, and (b) Design of new teacher education programs needs to start with a fresh slate of possibilities and allow for innovative and tradition-smashing methodology and logistics. Answers we offer to these issues and questions are partly speculative at this juncture, but insights gleaned from the following scenario may lead to some important experimentation.

A prerequisite to developing a plan for teaching integrated curriculum to preservice teachers is the need for communication and collaboration among faculty. As methods instructors we have taught courses and seminars without much consideration of other disciplines. We would chat with our colleagues about educational issues, but we rarely shared mutual interests or territories in our courses. It wasn't until the two of us began to talk about theoretical constructs of our disciplines that we realized how much we truly shared in curriculum theory. Those early conversations were critical in establishing a collaborative rapport. We can now talk about opening our syllabi and merging courses. It was a first step in designing something new and different.

Most important in this collaboration by faculty in designing integrated models is the knowledge that none of us is truly skilled in all areas. Various faculty members contribute expertise in the fields of science, mathematics, language arts, social studies, fine arts, health, and physical education. Working together we are able to create a sum greater than its parts.

A phenomenon that becomes a very powerful tool in teaching the integrated model is to model the integration. Over the past year, our integration workshops and courses have been a collaboration of planning and delivery. We work and teach as an integrated team. Students readily see the interactive nature of the instructors and curriculum. We plan to extend the use of the faculty team into a bold experiment in order to test the notions that collaboration and integrated curriculum play important roles in preservice teacher education.

Our elementary teacher education program employs a six-week block of curriculum seminars prior to a fifteen-week field experience and student teaching. Our experiment is planned for the six-week curriculum block. Formerly, each curriculum (methods) instructor developed a separate syllabi, taught during a specified number of hours, and submitted separate grades. The six-week term was a patchwork of different strategies, requirements, and expectations. Some instructors would require students to develop comprehensive units, while others required only student attendance. Some instructors tried to cover the gamut of the traditional methods course, while others dealt only with the state educational goals and objectives required of elementary teachers. Students complained of conflicting times, crossed theories, and mixed signals on pedagogical strategy.

The faculty team plans to change the paradigm to a narrative integrated framework. In order to accomplish this new model of preservice methods instruction, a pedagogy which matches the model is planned. Because college students have rarely experienced an integrated curriculum in their own schooling, the opening weeks of the term will provide that experience. Beginning with the first day of class, the activities will immerse them in a meaningful context and provide concrete experiences. We anticipate that the students will learn how the integrated model works by participating in it themselves.

Our students will be going on a trip along the old Oregon Trail. We chose the context of the Oregon Trail because of its temporal and physical presence in Eastern Oregon. Using this context transcends acquiring knowledge about this topic. The purpose of the Oregon Trail study is not to learn information about the Trail but rather to present a compelling context that empowers students to take ownership of their own learning. Each teacher institution would provide its own compelling context based on locale and on regional issues or problems and, ideally, should be selected with student input.

Our students will be the migrants on this journey. By being characters in this narrative, they will learn geography and climate. They will utilize historical, topographic and relief maps of the areas covered. They will build their character from reading and writing biographies, diaries and accounts of specific peoples and places during the migration. They will measure and plot rates of travel, sizes of conveyances, and dimensions of vehicles used to move people and commodities. They will engage in aesthetic pursuits of art, music and drama of the era and depict impressions of their readings and discoveries. They will think creatively, critically and deliberately in understanding the problems of migrants. The faculty team will be the scouts on this journey. They will offer guidance and advice about the territory ahead. They will provide resources and the expertise of one who has gone before.

As students travel along this trail, they will learn in a way that transcends disciplines because life's problems and pleasures are not limited to narrow subjects. The faculty team provides discipline-specific content and concepts when they are needed to help solve the problems encountered by the pioneers. Just as the guides on the historic Oregon Trail informed the pioneers, the faculty team offers those things that will make their students' trip not only less risky, but more pleasant: Maps can make the trip shorter and more secure; a musician can provide aesthetic recreation.

The opportunities for the science methods instructor to infuse concepts, processes, manipulation skills, and content into this framework are plentiful. By exploring how pulleys, levers, and inclined planes are harnessed to transport wagons up and down steep hillsides, learners will construct meaning for the concepts of energy and work. Students will learn how people apply scientific processes by observing, inferring, and hypothesizing about the abiotic and biotic factors of each biome encountered along the trail. Ingenuity to develop alternative technologies to solve problems along the trail encourages learners to use hand skills. Science content is represented in the geologic formations encountered, the climates endured, the ecological niches discovered, and the limits of the human machine including nutritional needs, disease, and survival.

After experience as learners in narrative-framed curriculum, these soon-to-be-teachers will have opportunities, with the guidance of the faculty team, to reflect on and analyze their experience, and to design similar units for elementary students. Children from the laboratory school will be invited to participate so that the pre-service teachers can try out their ideas immediately. We will transform the classroom into a living, learning environment.

CONCLUSION

American education is at the nexus of change. Technological, environmental, social and economic problems demand that we re-examine how we educate the next generation of citizens:

We are challenged to produce citizens who are able to intuit, create and solve problems in new ways in order to provide new products and new services in a highly competitive world market. They must be able to work with other people in complex environments. They must be able to adapt to new learning situations; in short, they must know how to learn. (Carnegie Forum, 1986)

Because the problems of the next century will be multidisciplinary in nature, an educational practice that deserves attention in preparing citizens is integrated curricula. Only by allowing students to explore answers to questions placed in broad contexts can they learn to "intuit, create and solve problems."

The integrated curriculum can be organized under a variety of frameworks. These frameworks use topics, concepts, processes or narratives as focal points for developing cross-disciplinary connections. Although some frameworks provide a higher possibility of producing a context for integrating subjects than others, all attempt to demonstrate the inter-connectedness of disciplines in exploring the real world.

Science educators ought to take particular notice of this trend toward curriculum integration, especially at the elementary level, not only because it provides an excellent opportunity to provide a meaningful context to solve problems associated with science and technology, but also because it looks forward to changes in teacher education. Pre-service education programs and the role of the methods instructor within them is changing. By creating collaborative faculty teams for curriculum/methods courses, integrated learning can be effectively modeled for future teachers. Science educators, who formerly were responsible for the gamut of methodological pedagogy, can now concentrate their efforts on communicating how their discipline contributes to an understanding of the world. By working with colleagues in other disciplines, exploring transdisciplinary formats of instruction, and providing future teachers with the opportunity to practice authentic problem solving, the first steps toward overhauling education can be taken.

REFERENCES

Andrews, J. (1985). *Very last first time.* New York: Macmillan.

Benjamin, S. (1989). An ideascape for education: What futurists recommend. *Educational Leadership, 47*, 8-16.

Bank Street College Project in Science and Mathematics. (1985). *The voyage of the mimi.* New York: Sunburst.

Barber, J. (1987). *Bubble-Ology: Great explorations in math and science (GEMS).* Berkeley, CA: Lawrence Hall of Science, University of California at Berkeley.

Born, T., & Jablon, P. (1990). Student involvement: A "must" for STS. *Teachers Clearinghouse for Science and Society Education Newsletter,* Spring.

Carnegie Forum on Education and Economy. (1986). *A nation prepared: Teachers for the 21st century.* New York: Carnegie Corporation.

Chaille, C., & Britain, L. (1991). *The young child as scientist.* New York: Harper Collins Publishers, Inc.

CEPUP (Chemical Education for Public Understanding Program). (1990). *Chemicals, health, environment and you.* Berkeley, CA: Lawrence Hall of Science.

Chronicle of Higher Education. (1989, November 8). City of New York undertakes a complete reform of teacher education. *Chronicle of Higher Education,* p. A14.

Elementary Science Study. (1968). *Bones.* St. Louis: McGraw-Hill.

Fogarty, R. (1991). Ten ways to integrate curriculum. *Educational Leadership, 49*(2), 61-65.

Gamberg, R., Kwak, W., Hutchings, M., & Altheim, J. with Edwards, G. (1988). *Learning and loving it.* Portsmouth, NH: Heinemann Education Books, Inc.

Goodlad, J. (1984). *A place called school* . New York: McGraw-Hill.

Jaeger, M., & Lauritzen, C. (1992). *Curriculum integration: A constructivist approach.* Paper presented at the 5th Conference of the North America Construct Network, Seattle, WA.

Jensen, J. (1989). *Stories to grow on: Demonstrations of language learning in K-8 classrooms.* Portsmouth, NH: Heinemann Educational Books, Inc.

Johnson, S. (1991). *Science to sink your teeth into: A small group introduction to designing an experiment.* Muncie, IN: Biology Department, Ball State University.

Johnson, T., & Louis, D. (1989). *Bringing it all together.* New York: Collins.

Kovalik, S., & Olsen, K. (1986). *Teach for success: An integrated thematic approach to teaching science.* San Jose, CA: Discovery Press.

Matson, R. (1986). *Green thumbs: Radishes.* Canby, OR: TOPS Learning Systems.

Matson, R. (1977). *Graphing.* Canby, OR: TOPS Learning Systems.

Oregon State Department of Education. (1989). *Common curriculum goals for science.* Salem, OR: Oregon Department of Education.

Pappas, C., Kiefer, B., & Levstik, L. (1990). *An integrated language perspective in the elementary school.* White Plains, NY: Longman.

Pottenger, F. (1990). *A model for organizing curriculum with technological content.* Honolulu, HI: DASH, University of Hawaii.

Reuter, J. (1989, August/September). Select a topic—any topic. *Writing Teacher.* August/September, 19-21.

Routman, R. (1991). *Invitations.* Toronto: Irwin Publishing.

Shoemaker, B. (1991). Education 2000 integrated curriculum. *Phi Delta Kappan, 72*(6), 793-797.

Shymansky, J., & Kyle, W. (1991). *Establishing a research agenda: The critical issues of science curriculum reform.* NARST/NSF Conference Report.

Sneider, C. (1988). *More than magnifiers.* Berkeley, CA: Lawrence Hall of Science, University of California.

Thier, H., Karplus, R., Lawson, C., Knott, R., & Montgomery, M. (1988). *Interactions and systems.* Nashua, NH: Delta Education, Inc.

Vann, A. S. (1988). The curriculum cup runneth over. *Educational Leadership 46*(1), 60.

Chapter 3

Integrating Knowledge Bases: An Upper-Elementary Teacher Preparation Program Emphasizing the Teaching of Science

Joseph S. Krajcik
Phyllis Blumenfeld
Mary L. Starr
Annemarie Palincsar
Brian P. Coppola
Elliot Soloway

This chapter describes the first year of a model preservice teacher preparation program that focuses on improving the teaching of science at the elementary level and describes some of the changes in the program as a result of the first year's experience. The program was designed to incorporate work in science teaching (Sanford, 1987; Smith & Neale, 1989) and teacher education (Borko & Shavelson, 1990; Shulman, 1986a, 1986b; Wilson, Shulman & Richert, 1987) to help preservice teachers develop and integrate knowledge of physical science content, pedagogical content, and the psychological foundations of teaching and learning in classrooms. Our aim is to enable new teachers to craft and conduct educational experiences designed to deepen student understanding of fundamental science concepts.

Within the program we address several problems characteristic of preservice programs. One problem is that courses often are discrete and little attempt is made to help students see connections among what is presented. A second and related problem is that content and methods courses are not linked so that students do not get the opportunity to see how what they are learning in the subject areas might be taught to children. A third problem is that clinical experiences are not always linked specifically to other course material and in the elementary grades frequently do not include exposure to exemplary science teaching. A fourth problem is that technological tools that can provide effective help for teacher preparation students as they plan instructional units do not exist. We attempt to deal with these problems by: (a) integrating coursework in physical sciences, science methods, and foundations, including educational psychology and introduction to teaching; (b) providing extensive exposure to teaching methods through extra coursework and practicum; (c) linking coursework to focused clinical experiences to provide a context for learning and practice; and (d) developing technological support to aid preservice teachers in learning, integrating, and applying these knowledge bases. Our aim is to increase dialogue regarding elementary science teacher preparation in the hope of developing an institutional model forging links between content, methods, and foundations. This includes articulation not only within courses by faculty but also across all aspects of the curriculum and across the several semesters of the program.

In what follows, we (a) review the evolving literature in teacher education and development; (b) discuss our program for teacher preparation, focusing on course design and integration, and our work with supervising teachers; (c) describe the development of preservice teachers' understanding within the first year; and (d) present an initial evaluation of the program and plans for revision. In this way we hope to help faculty in other universities anticipate problems and possible solutions in creating similar programs in their own universities.

RATIONALE AND BACKGROUND

Recent research emphasizes that teaching is a highly complex cognitive activity, where diverse sources of knowledge must be integrated. New perspectives focus on the teacher as a reflective professional (Schön, 1983), in contrast to the stress on skills and techniques that have dominated the field for many years. Findings (see review by Clark & Peterson, 1986) indicate that teachers' knowledge and thoughts have a profound effect on the way they teach and how students learn. These studies also point to the importance of teaching cycles--planning, practice, reflection, and revision--for improving teachers' expertise. Teaching must be represented to preservice teachers as a cognitive, problem-solving activity organized around subject matter and common pedagogical events.

One purpose of coursework must be to help preservice teachers develop rich sets of knowledge that will help them design units and lessons. This knowledge, however, cannot be communicated as a fixed set of rules or information; teachers must construct their understandings (Smith & Neale, 1989). Shulman and his colleagues (Grossman, 1990; Shulman, 1986, 1987; Wilson, Shulman & Richert, 1987) have described the diverse knowledge domains (i.e., content, pedagogical content, pedagogy, curriculum, and learners) that teachers, including novice teachers, must draw on in teaching. Recent work points to the influence and importance of subject matter knowledge (Smith & Neale, 1989). The lessons of more knowledgeable novices as well as more experienced teachers are more conceptual, more flexible, and more responsive to student needs (Borko & Livingston, 1990). New teachers also develop pedagogical content knowledge, knowledge of how to represent and teach the concepts. They struggle to develop representations via examples, explanations, metaphors, that take account of the diverse interests and abilities of learners. This capacity to transform content knowledge into forms that are pedagogically powerful and adaptive to particular groups of students is at the core of successful science teaching.

Shulman's research, and the work on the differences between experts and novices and among novices themselves, points to a second purpose of preparation, helping preservice teachers integrate these knowledge bases in planning for instruction. Expert teachers do more planning, preparing mental scripts, to guide the direction of their lessons (Berliner, 1986; Clark & Yinger, 1987; Leinhardt & Greeno, 1986). Experts' plans or agendas are more explicit and richer in interconnections. They include more detail about teacher instructional behavior, expected student understandings and behavior, possible alternatives, and more explicit routines for managing common classroom activities and circumventing potential difficulties. Similarly, research by Borko (Borko, 1989; Borko, Lalik & Tomchin, 1987; Borko & Livingston, 1990) indicates that one factor that differentiates stronger and weaker student teachers is this type of planning. It is encouraging to note that preliminary results of several programs suggest the benefits of preparing preservice teachers to be more "thoughtful" in how they plan for instruction (Borko & Niles, 1987; Neely, 1986; Zeichner & Liston, 1987).

New approaches to planning stress problem-solving and decision-making. The problem for the teacher is how to design a set of experiences (either led by the teacher or done by the students) to help a particular group of children (age, ability level, with certain prior knowledge and skills) develop understanding of the concepts under particular conditions and constraints. We view planning as problem solving. It is also important to note that plans need not be formal or written; they are often mental representations or scripts for action. In this sense, plans are cognitive. Moreover, research indicates that many teachers use plans as "road maps" or guides that they change based on classroom conditions, student reactions, and their own evaluation. Thus, it is the process of thinking through what to teach, how to teach it, anticipating and solving problems, not simply the enactment of the plan itself, that is beneficial (Clark & Yinger, 1987).

A third purpose of teacher preparation is to provide clinical experiences--opportunities to contextualize learning, and to practice, reflect, and revise plans, under the careful supervision and tutelage of master teachers. Such opportunities help preservice teachers learn what Doyle (1986) has termed "classroom knowledge" of common pedagogical events. This knowledge is fundamental to effective classroom management, which is often quite problematic and of great concern to novices (Kagan, 1992). A fundamental difficulty for new teachers is to create and manage an environment that allows them to concentrate on teaching science concepts that provide opportunities for students to learn. Evidence indicates, however, that clinical experiences need to be focused on specific issues; having students make general observations rather than tackle actual problems of teaching via analyzing events or teaching themselves does not aid in preservice teacher development (Kagan, 1992).

Unfortunately, most elementary teacher preparation programs are not designed to help preservice teachers to construct relevant understandings of the knowledge bases underlying teaching, to integrate knowledge bases in planning, or to put these understandings into practice in the classroom setting (see Woolfolk, 1989; for review). Certainly, coursework covers much relevant information that would form the basis for more effective teaching. But the courses are not coordinated with respect to approach or content, so that preservice teachers receive little practice in what the research on teacher education has shown is critical: systematically integrating content with methods and with underlying pedagogical and psychological principles. Moreover, clinical experiences often are not coordinated with other course preparation and vary tremendously with respect to the quality of instruction preservice teachers see and the quality of supervision they receive. As a result, preservice teachers often have little guidance as to how to accomplish this integration or how to think about and revise their initial teaching efforts. A consequence of current preparation programs is that teacher education students experience considerable difficulty during student and first-year teaching drawing on, integrating, and effectively implementing what they learned in university courses (Borko & Livingston, 1990).

PROGRAM OVERVIEW

We have designed a two-year program of preparation that emphasizes the teaching of science in the upper elementary grades. Physical science, chemistry, and physics are emphasized because these are areas in which elementary teacher education students typically have the most difficulty. The content of all the courses converges around providing elementary preservice teachers with the opportunities to develop a strong conceptual base in physical science and clear understanding of how to teach these concepts to pre-and early-adolescent students.

Preservice teachers enter the program as a cohort group and continue in the program through two years of teacher preparation, including their student teaching experiences. As many students as possible are followed during their first year of teaching both to provide support and to identify problems they encounter. Students fulfill university and state requirements for certification during their junior and senior years. During their initial semester, students take courses as a group. They enroll in chemistry, science methods, and foundations courses in educational psychology and in introduction to teaching in the elementary school. The latter serves as a link to a six-hour per week practicum placement that students attend. During the second semester, students enroll in physics, a second science methods course, practicum placement, and other courses necessary for certification including math and reading methods. During the third semester, the cohort aspect of the program is somewhat minimized as students continue to fulfill requirements for individual majors and for certification. These include courses in social foundations, reading, and art. The cohort comes together during the last semester, when they student teach during the senior year and convene for a student teaching seminar. Student teaching occurs in classrooms in which science is taught. Supervision of student teaching is done by members of the program faculty who supervised the practicum experiences.

Continuity among courses and integration of course content were established through a common set of assignments focused on the development of unit designs and lesson plans that were implemented in practicum classrooms. The content of the unit design and lesson plans focused on the teaching of physical science.

These tasks were chosen because they are authentic. This format represents our attempts to anchor instruction. (for a discussion of anchored instruction see The Cognition and Technology Group, 1990). That is, they are real tasks that teachers carry out; they contain problems teachers must solve; and they promote integration of knowledge bases because they provide opportunities to grapple with many issues simultaneously in addressing problems central to teaching rather than focusing on isolated difficulties.

The planning of unit designs provides opportunities for students to combine conceptual understandings of content with pedagogical and pedagogical content knowledge. Each unit contained concept maps of the content, goals of instruction, activities for students, instructional methods (including explanations, demonstrations, etc.), and evaluations. For each component, preservice teachers provided justifications based on information gained from science content, science methods, foundations of teaching, and practicum experience. Although preservice teachers had several responsibilities in their placements including opportunities to observe effective teaching, to interview elementary students about their science understanding, and to assist the practicum teacher with instruction, the most important task was to plan, conduct, reflect on, and critique a three-day teaching episode drawn from their unit designs. The goal of the teaching was to give students experience with deciding how to select, represent, and present content across several days for a group of children with whom they were familiar and to draw on the knowledge bases to make and explain choices. They taught chemistry during the first semester and physics during the second. It is worth noting that this is considerably more teaching than students would have experienced during the first year in typical elementary preparation programs, and it required a great deal of time from program staff and supervising teachers.

The courses contributed to students' ability to develop unit designs and teaching episodes in different ways. Preservice teachers learned key concepts in chemistry and physics. The content courses stressed the construction of conceptual, qualitative understanding and application. Stress was placed on developing conceptual and process skills simultaneously; preservice teachers made observations of natural phenomena, asked questions, made predictions, and drew conclusions from data. In science methods students further developed their own understanding of the concepts and began to translate the content into meaningful representations for elementary students. In educational psychology, they considered issues in teaching and learning, motivation, development, assessment, and classroom management that should be taken into account when making instructional decisions. Introduction to the Elementary School served as organizer of practicum experiences and discussed the inner workings of classrooms and schools including, teacher roles, the impact of community on school culture, influences on curriculum, and the educational and social function of cooperative groups. The program paid special attention to techniques and methods for working with at-risk populations by building such methods into all aspects of the curriculum. We were committed to placing elementary students in schools with considerable at-risk enrollments and with teachers who have the qualifications for working with such populations.

SUMMARY OF FIRST-YEAR ACTIVITIES

At the time of this writing, we have completed the first year of the program and are in the beginning of the second year. The first cohort was composed of volunteers from students in the School of Education. They were relatively typical of elementary education students at our institution; most were juniors, females, and in their early twenties. A few already had an undergraduate degree and were returning for certification. The students had varying backgrounds in science; we especially encouraged students who had minimal credit in science but who wanted to improve their ability to teach science to children to enroll in the program.

From our experiences in year one, we learned a great deal about what it is to conceive of and develop an innovative preparation program, especially with respect to integrating teaching among faculty in both education and in the sciences, establishing a working relationship with supervising teachers, and monitoring and supporting the development of preservice teachers. Below, we describe our experiences and insights we have gained about each of these three areas.

Integration of Courses

The program addresses the problems described above by radically changing the way preservice teachers experience instruction within content courses and methods courses. Integration among courses was one method through which we helped to foster the development and synthesis of knowledge bases for the preservice teachers. Linking occurred among science content and methods, and among courses in education. Science methods served as a bridge between the content courses and education courses.

During the summer preceding the inauguration of the program, faculty met to consider how integration might best be achieved. We determined content, developed themes, and designed assignments that would cut across the courses. To select content, we first outlined what each course typically covered. We identified areas of unnecessary redundancy that result from failure to integrate courses. In addition, we determined areas of overlap where the same ideas could be dealt with but where each course could make unique contributions to students' understanding of the idea. For instance, issues of learning were central to each of the courses. Preservice teachers wrestled with issues of how students construct knowledge and the role of misconceptions and prior knowledge in learning in educational psychology, considered science specific misconceptions and issues of learning science in science methods, and discussed the role of culture and community on learning as well as how testing is used to define whether learning has occurred in the introduction to elementary school course. In addition, the preservice teachers interviewed children in their practicum classrooms to determine their understandings of concepts being covered in the chemistry course and which they were planning to teach. We also decided what would be a reasonable sequence for covering those ideas so that wherever possible they would be dealt with at the same time in the different courses. These discussions were quite challenging. Faculty needed to come to grips with key concepts in each others' fields, explore similarities and differences in how these concepts are treated, and also give up typical ways of sequencing and covering topics to accommodate to the needs of integration.

We decided to use the design of a unit, and the planning, practicing, and reflecting on part of the unit as program-wide assignments that would facilitate integration of the courses for students. Moreover, rather than focus on theoretical issues in each field, the focus was on helping students to develop understandings of their interaction to better understand what to take into account when planning and conducting instruction.

We also developed themes that served to further focus integration of courses. The themes are broken into five distinct categories: learning, teaching, student diversity, technology, and context. Issues were addressed in a manner that developed these themes within and across courses and between coursework and practicum experiences. Examples of themes include: (a) learning is a constructive enterprise that takes place by interaction between teacher and students and among students themselves, and (b) teachers enact and shape the curriculum by using various knowledge domains to make decisions. Our goal was for these themes to be reflected in student beliefs and instructional planning and practice.

We also sought meaningful integration between science methods and science content courses. A variety of techniques were used to help develop the integration. The science methods instructor, chemistry instructor, and supporting teaching staff met during the summer to plan the courses. Planning sessions for integrating physics and science methods occurred in the fall. Integration between chemistry and science methods was enacted through a team teaching approach with the two courses meeting back to back for four hours per week throughout the fall semester. This structure allowed for the sharing of teaching responsibilities where the chemistry instructor participated in discussions related to the teaching and philosophy of science and the methods instructor presented analogies and examples to illustrate how the content could be represented for children. Common assignments and activities that spanned both courses such as concept mapping, lesson planning, and research projects also helped to establish the integration. The unit designs, described above, also helped to integrate science content and method courses with other education offerings. Both the science methods and chemistry teaching staff contributed to students' development of the units on topics covered in the chemistry course.

Integration between science methods and physics content occurred through physics laboratory activities and teaching assignments. The physics instructor structured the laboratory activities so that preservice teachers made connections between the science content and representations appropriate for elementary students. Frequently, the science methods teaching staff would attend the laboratory sessions to help the students with their activities. Translating the physics content into meaningful representation was also accomplished by the students' presenting demonstrations that illustrated physics content during laboratory sessions. In science methods the instructor also focused on how the content in lecture could be translated for children. Preservice teachers also developed and taught portions of a unit that focused on one of the physics topics. The physics laboratory instructor helped the students to develop ideas on how to represent the content.

Overall, we learned a great deal about what it takes to integrate courses. Several factors must be in place to even attempt such integration. First, as a group, the faculty must share and be committed to the same overriding goal, the preparation of quality teachers. Second, they must be committed to devoting the time to exploring what this means so that the group constructs a common understanding. Third, and most practically, faculty must stay in close contact with each other throughout the course of the program to continue to develop and clarify ideas and to make minor and major changes as needed.

Relationships with Teachers

We view the practicum supervising teachers as central to our work. We asked for a considerable commitment from the teachers and included them in much of the decision making. The teachers willing to devote time and energy to this endeavor had two common characteristics: (a) sharing an interest in the development of preservice teachers, and (b) a valuing of science taught at the elementary level. We expected these supervising teachers to attend planning meetings held three times a semester and to organize classroom activities to allow preservice teachers an opportunity to observe and participate in particular learning experiences. We were careful to include the teachers in planning because research suggests that the benefits of practicums are best realized when clinical experiences are focused and melded to university work (Kagan, 1992).

Along with classroom visits by program staff, a series of evening meetings with the supervising teachers was a key feature of our program. These meetings allowed us to discuss issues in preservice teacher preparation, provide information about the course content and assignments, receive feedback concerning how preservice teachers were doing in the field, and provide informal opportunities for preservice teachers to interact with their supervisors.

Our experience suggests that some preservice teachers were reluctant to get involved in classroom activities, while others were quite comfortable jumping in immediately. Moreover, teachers had different expectations for what students should be doing. In addition, although we emphasize science education, because students are being prepared for general certification they need to learn about other aspects of elementary classrooms including other subject areas and responsibilities teachers fulfill. Based on our experiences, in cooperation with the supervising teachers, we developed a list of classroom activities for preservice teachers. The activities (see Table 1) are designed so that students experience different aspects of an elementary teacher's responsibilities, including working with children in class and out as well as dealing with administrative responsibilities and with parents. The activities vary in level of difficulty and responsibility, from assisting children during seatwork, to doing a lesson preplanned by the teacher, to planning and conducting a lesson independently. Preservice teachers are expected to participate in instructional activities in all elementary subject areas; however, science is the topic of their lesson planning and teaching. We requested that the teachers discuss lesson plans with the students and also provide feedback after their instruction.

Table 1. Suggested preservice teacher's practicum experiences

Working with Students

Class Activities

Individually:

- Partnering with student in activities.
- Tutoring on problem areas.

In small groups:

- Giving assistance with extra assignments.
- Provide enrichment activities.

Whole class:

- Introducing the rules of a game.
- Read to students.
- Teaching lessons.
- Go on field trips with the class.
- Help students with a class newspaper.

Outside of Class Time:

- Play with students at recess.
- Stay after school to help students.
- Take a turn waiting by the bus before or after school.
- Become involved in student clubs.
- Lead special interest groups.

Responding to Student Work:

- Read and respond to student journals.
- Float during lesson and guided practice.
- Reviewing/grading student papers.

Helping the teacher

- Proctor standardized tests.
- Create interactive bulletin boards.
- Create and duplicate student worksheets.
- Assist in setting up activities.
- Run audio—visual equipment.
- Videotape the teacher teaching.

Professional Activities

- Converse with supervising teachers about lesson planning.
- Attend parent night.
- Attend staff and curriculum development meetings.
- Attend professional organization conferences.

We also instituted several practices to facilitate communication and coordination among university and school participants including, a beginning of the term sheet detailing course content and requirements and a biweekly sheet indicating assignments due for class and assignments such as interviewing pupils that required some practicum time. In addition, the practicum coordinator made several visits to the classrooms. The purpose was to provide the supervising teacher with program information, learn of any difficulties the preservice teachers might be experiencing, discuss with the preservice teachers issues related to classroom events, and observe the preservice teachers.

We wanted teachers to give students a feel for the "backstage" of teaching rather than only being exposed to its enactment. We hoped they would share with preservice teachers how they make decision, how they plan lessons, how they reflect on their teaching and make changes. This goal was difficult to achieve. First, the teachers could not take time out during the day to converse with the practicum students. Unfortunately, because of busy class schedules, the practicum students often could not arrive before class or stay after for discussions with the teachers. Some supervising teachers used evening phone calls to consult with students. Therefore, we also used two of the evening meetings as an opportunity for preservice teachers to meet informally with the supervising teachers. The first evening session focused on discussions of the "real world of teaching." Each preservice teacher submitted questions regarding areas of interest or concern. They asked questions such as: How do you balance home and school life? Is it always this much work? How do you get children to listen to you? The teachers and students broke into small groups to discuss these questions. For the second session, the procedure was reversed; supervising teachers posed questions to be answered by the preservice teachers. The supervising teachers asked questions such as: What are your perceptions of the classroom? What kinds of classroom events surprised you? Why do you want to be a teacher? These sessions proved very successful; many students commented that they were one of the highlights of the semester.

Working with Elementary Preparation Teachers

Working closely with a small group of preservice teachers has taught us about novices and how they develop with respect to belief, content knowledge, and teaching abilities. We also discovered the importance of dealing with novices by building a cohesive cohort, providing individual attention and having consistent personnel to deal with their concerns and personal needs during the difficult transition from college student to elementary school teacher.

Teacher Development

To determine how preservice teachers change over the course of the year and to make decisions about our instructional program, we collected information using: (a) semi-structured interviews of beliefs about teaching and learning and knowledge of physical science content, (b) videotapes of classroom teaching and audio tapes of reflections on the lessons, and (c) written unit and lesson plans. The data are being used to gain insights into ways in which preservice elementary students develop understanding of and ability to teach science. Although the data have not been fully analyzed, some preliminary patterns have emerged. These patterns match many of the findings reported by others concerning the beliefs, conceptual understandings, and teaching difficulties of preservice teachers (Borko & Livingston, 1990; Kagan, 1992). Our goal is to determine how students change and more specifically whether a program such as ours can help students overcome some of the problems that plague student teachers, such as difficulties that stem from limited content and pedagogical content knowledge, from lack of pedagogical knowledge about how to translate beliefs about learning into action, and how to manage classrooms.

With respect to beliefs, preservice teachers predominantly saw teaching as transmission and learning as knowledge accumulation. Initially, they saw science teaching as similar to other teaching, except harder because teachers need more content knowledge. By the end of the year, the ideas about learning began to change; however, these were not accompanied by complementary changes in their ideas about teaching. For instance, although the preservice teachers now mentioned the importance of children's prior knowledge and students actively being engaged in the learning activity, they did not extensively discuss how such ideas could be used in classroom teaching.

As one measure of the preservice teachers' change in content knowledge, we administered semi-structured interviews before and after both the chemistry and physics courses. The chemistry interview explored ideas of chemical and physical change, the particulate nature of matter, differences between compounds and pure elements and states of matter. The physics interview covered ideas of motion and force, gravity, the nature of light, simple electrical circuits, and the nature of sound. Initially, analyses of the data indicated that the preservice teachers involved in this program displayed a wide range of levels of scientific understandings both before and after the content courses. However, in certain cases it was clear that understandings improved over time. For instance, the preservice teachers had noticeably clearer notions of the differences between chemical and physical changes in the post interview as compared to the first interview. Additionally, although only a small number of the preservice teachers successfully completed basic electrical circuit tasks in the pre-course interview, most were successful in the post-course interview.

We have also been interested in examining how content knowledge is represented in the students' teaching efforts. The three day teaching episodes for fall and winter semesters were analyzed for content representation (e.g., what is included, how is it explained), instruction (what methods are used, patterns of questions and feedback, lesson cohesiveness), and managerial considerations (e.g., monitoring, pacing). We also examined students' own reflection on the strengths and weaknesses of their teaching. During the first term the teaching of preservice teachers was characterized by many of the difficulties of student and first-year teachers (Borko & Shavelson, 1990; Grossman, 1990; Shulman, 1986;). Their representation of content focused mainly on definitions and on procedures rather than on concepts and the investigatory nature of science. They rarely elicited children's prior knowledge. They also had difficulty with management. By the second teaching episode several first year preservice teachers questioned children to create lists of their ideas, referring to the ideas within the content discussions and crediting particular children with having offered the information. Also, the preservice teachers were asked to specifically plan the content explanations, analogies, or comparisons that they would use with the children. They developed their own analogies and metaphors and used examples that were consistent with children's prior knowledge. They still had difficulties answering and using children's questions and missed many opportunities to develop content understanding.

The problems we found are those typically exhibited by student teachers. Change takes time and the process of learning to teach needs to begin very early in the teacher preparation program. Improvement in instructional management during practicum teaching experiences suggests that early attention to these difficulties may help improve student teachers' experience and performance. unless preservice teachers have survival skills of good instructional management techniques, they are likely to focus almost exclusively on management and control. Our findings suggest that an early emphasis, during practicum placements, on instructional management including pacing, timing, and monitoring would assist preservice teachers in attending to content development. Moreover, we are interested in examining if student content knowledge improves when they are required to plan and teach lessons associated with content. However, it is evident that content knowledge does not translate directly into effective conceptual representation for children and that such representations develop slowly over time (Grossman, 1990; Krajcik, Layman, Starr & Magnusson, 1991).

It is important to note that these students have engaged in considerably more classroom science instruction than is typical during the first year in most teacher preparation programs. Our interest is in determining whether these experiences are beneficial for preservice and first-year teachers, so that some of the weaknesses and difficulties experienced during these times are minimized. To this end, we will continue to follow our first cohort of preservice teachers during the second year of preparation and into their first year of teaching.

Responding to Preservice Teachers' Needs

The transition from university student to professional teacher is difficult because students are developing visions of themselves as teachers and learning to deal with a world of schools that does not match their ideal image. They need to explore their changing beliefs about what it means to be a teacher, link what they were learn at the University with what they are seeing at their practicums, and deal with their personal reactions to classroom events. We used a cohort approach, discussion sessions, and a program coordinator to support students during this transition.

The preservice teachers entered the program as a cohort and developed into a cohesive group. Several factors contributed to the cohesiveness of the cohort. First, students took all courses together during the first term and several together during the winter. Second, we were able to equip a computer laboratory for the program where students spent long hours together. Having a physical location where they could work and congregate gave students the opportunity to share ideas and resources and discuss assignments and react to each others' teaching. The fact that students decorated the room with posters, brought bean bag chairs and other items to make the room homey is an indication of their attachment to the location. Third, they were placed in their practicum experiences in pairs. This pairing allowed preservice teachers an opportunity to share their classroom experiences and to grow through the discussion of the different perspectives they brought. In addition, they were forced by this arrangement to collaborate with each other about their teaching, both in planning and in reflection. In accordance with the focus on teaching and reflection within the program, preservice teachers also spent time watching the videotapes of other cohort members, critiquing and supporting each other in the process. In this way they were able to share both successes and failures. Students reported that the social and supportive aspects of a positive group atmosphere were critical to the quality of the overall program experience. Having a close knit group seemed especially important in a large and sometimes impersonal university.

Another way we accommodated student needs was by holding weekly discussion sessions where issues that arose in practicums or in the program were discussed. These conversations served to help students deal with difficult issues and also provided a forum where individuals could explore their own attitudes and reactions. Elementary preservice teachers could discuss as well as disagree about educational policy, classroom practice, and effective teaching. They could also work together to resolve affective reactions to troubling classroom events, such as insolent children, unfair teachers, aggression, and other inappropriate behaviors. This forum served a very important purpose, both in stimulating individual growth as well as promoting group support.

In addition, we appointed a program coordinator, whose responsibility it was to be knowledgeable about each of the courses, the practicum, and the assignments. Although all the instructors were familiar with the preservice teachers, having one central individual who served as information source, tutor, counselor, and friend proved to be important in helping preservice teachers during the difficult transition from thinking like university students to thinking like teachers engaged in professional training.

Another area of consistency, in addition to the program coordinator, was having continuity in personnel across semesters. The individual who supervises preservice teachers' practicum also supervises their student teaching. Whereas student teachers from other programs are quite worried about visits from supervisors with whom they have limited familiarity, our students are quite comfortable. For them, a visit from the supervisor seems like an extension of what they experienced during practicums, and debriefing and reflection sessions. Many have indicated they think this aspect of the program should be maintained.

Based on student end-of-the-year reports and student behavior, we established a learning community among preservice teachers by building a cohesive cohort, providing forums for discussion, and mechanisms for individual attention and support. These are important elements in promoting student motivation and development in teacher preparation programs.

REFLECTION AND REVISION

We have tried to impress upon our first elementary science cohort the importance of reflection and revision as a central component of any teaching task. With this in mind, we examined the strengths and weaknesses of the program during the first year and instituted revisions based on initial analysis of student data, reports of supervising teachers, student evaluations, and our own impressions. We conclude this chapter by highlighting some of the changes we have made in our preparation program.

Integration of the courses is a vital part of this program. We initially integrated the education and content courses by focusing on important ideas and themes to which each course made a contribution and by two main program assignments; development of unit designs, and planning, enacting, and reflecting on a three-day teaching experience. Faculty planning during the summer and throughout the year helped to highlight what we wanted to emphasize and helped organized how it could be best presented. We experienced two main problems with this approach. First, our instruction remained topic centered. That is, we integrated across courses by focusing on common areas, like representing content, questioning, working with activities, and encouraging student collaboration. Our aim was for students to apply and integrate the ideas explored as they planned units and teaching. While problems of teaching and learning are the heart of our program, we did not explicitly use a problem centered approach (i.e., focusing on the problems in designing units and planning, and conducting teaching) as the organizer of our classes. Second, a related difficulty was that we found ourselves increasingly driven by the preservice teachers' interests and needs as the semester progressed. The impetus behind these interests seemed to be the course assignment to create a unit plan, their own reflections on experiences in the schools, as well as their developing understanding of teaching as a profession.

As we reviewed this approach, we determined that students needed more help in accomplishing the translation from coursework into these assignments. As mentioned above, and similar to what others have found, preservice teachers had particular difficulty putting the ideas into practice during classroom teaching. Although we had dealt with content pertinent to both tasks and worked on applying that content (i.e., selecting and modifying activities, and determining how to manage small groups) we had never directly worked on the whole problem. Also, recall that one of our goals is to promote constructivist classrooms where learning derives from students working on authentic problems. We decided that our instruction did not overtly model such an approach. Therefore for the second year of the program, we adopted a more problem-based approach. The problem posed for students is how to design lessons and units in a manner that promotes learning and how to implement these lessons. To accomplish this goal, we are having students engaged in "apprenticeship" teaching experiences during the first two months of classes. For these experiences students are divided into groups of four. They work with a unit, a water project developed by TERC and published by National Geographic--What is Our Water? The unit focuses on a driving question, where children collaborate to gather and interpret data, investigate the problem, and communicate their findings to others via telecommunications.

Each week, two groups are assigned a science lesson from the unit to plan. However, we encourage the groups to plan independently. We use the same lessons for each group so that the decisions made and the reasons for the decisions can be contrasted for both groups. The lessons were selected to cover various aspects of teaching, such as selecting, modifying, and conducting small group activities, introducing new information, leading discussions, and helping students plan experiments and interpret data. Two members from each group are responsible for implementing the lesson for their peers and faculty. For each week the cohort is given a set of focus issues, such as using questions to develop ideas and links among ideas, promoting discussion or collaboration. Each week a new set of issues is added to those already posed. The issues build on each other so that those dealt with in previous weeks are not isolated but are related to larger problems of planning and implementation. This "apprenticeship" teaching should not be confused with skilled-based "microteaching" that characterized teacher preparation for many years. The students and faculty each view tapes of the teaching and prepare written comments based on the issue question for discussion during class time.

The program courses help students develop a knowledge base about the issues raised and also help students apply this knowledge immediately to the problems of designing and conducting instruction. Students at the same time are getting experience in their practicum classroom; they wrestle with questions about their classrooms that are similar to those posed for the "apprenticeship" teaching. This approach is more directly related to the key tasks we have posed for students: designing units, and planning and conducting a three-day teaching experience. We plan to determine it's effectiveness by comparing the performance of the first and second cohorts on both tasks. We believe that the changes we are making in instruction will impact directly preservice teachers' ability to integrate their understanding of science content, teaching, and learning.

We have found that developing a cohesive cohort, providing discussion opportunities for students to air their concerns and having consistent program faculty are important components of effective teacher preparation programs. Our findings also suggest that an early emphasis on classroom teaching with considerable support from coursework and faculty should help assist preservice teachers in more effectively developing content for children during their student teaching. It also highlights the importance of attending to students beliefs and developing ideas about themselves as teachers. Moreover, our work indicates that student's content knowledge is enhanced when they are required to plan and teach lessons associated with that content. However, it is also evident that content knowledge does not translate directly into effective conceptual representation and that such representations develop slowly over time.

Through the analysis and synthesis of the data we are collecting we will be able to comment on the growth and development of these preservice teachers We will continue to follow the preservice teachers through the second year of teacher preparation and into their first year of teaching. These investigations should contribute to the field of science teacher education by tracking longitudinal changes in content knowledge, beliefs about teaching and learning, pedagogical knowledge and pedagogical content knowledge, and ability to integrate and apply that knowledge during teaching. Also, documenting the impact of our efforts will serve to provide valuable information for others about program design for teacher program.

ACKNOWLEDGMENTS

Partially funded through a grant from the National Science Foundation. Blumenfeld, P., Krajcik, J. & Soloway, E. (1991). Upper Elementary Science Teaching: Integrating the Knowledge Bases, TPE 9150020.

A software program, Instruction by Design (IByD) is used by the students to plan for instruction. IByD provides opportunities for students (1) to construct knowledge bases about content, methods, instruction, student learning, and motivation and (2) to develop from these knowledge bases a series of considerations that should be taken into account when making decisions about teaching. IByD also contains a series of templates for components of plans like concept maps, goals, student and teacher activities, and evaluation where students design and justify their plans and provide rationales based on considerations drawn from knowledge bases. It also provides opportunities for students to graphically illustrate and explain the connections among the components of their plans. Our aim is to provide an environment that promotes better integration of information, systematic application of information to decisions, more explicit reasoning about decisions and more well-developed plans.

REFERENCES

Berliner, D. C. (1986). In pursuit of the expert pedagogue. Educational Researcher, September, 5-13.

Borko, H. (1989). Research on learning to teach: Implications for graduate teacher preparation. In A. Woolfolk (Ed.), Research perspectives on the graduate preparation of teachers (pp. 69-87). NJ: Prentice Hall.

Borko, H., Lalik, R., & Tomchin, E. (1987). Student teachers' understandings of successful teaching. Teaching and Teacher Education, 3, 77-90.

Borko, H., & Livingston, C. (1990). Cognition and improvisation: Differences in mathematics instruction by expert and novice teachers. American Educational Research Journal, 26, 473-498.

Borko, H., & Niles, J. (1987). Descriptions of teacher planning: Ideas for teachers and researchers. In V. Richardson-Koehler (Ed.), Educators' Handbook: A research perspective (pp. 167-187). NY: Longman.

Borko, H., & Shavelson, R. (1990). Teacher decision making. In B. Jones, & L. Idol (Eds.) Dimensions of thinking and cognitive instruction. (pp. 311-346). Hillsdale, NJ: Erlbaum.

Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. Wittrock (Ed.), Handbook of Research on Teaching (pp. 255-296). NY: Macmillan.

Clark, K., & Yinger, R. (1987). Teacher planning. In J. Calderhead (Ed.), Exploring teacher's thinking (pp. 84-103). London: Cassell.

Cognition and Technology Group at Vanderbilt (1990). Anchored instruction and its relationship to situated cognition. Educational Researcher, 19(6), 2-10.

Doyle, W. (1986). Classroom organization and management. In M. C. Wittrock, (Ed.), Handbook of Research on Teaching (pp. 392-431). NY: Macmillan.

Grossman, P. (1990). The Making of a teacher: Teacher knowledge and teacher education. New York: Teachers College Press.

Kagan, D. M. (1992). Professional growth among preservice and beginning teachers. Review of Educational Research, 62, 129-169.

Krajcik, J., Layman, J., Starr, M., & Magnusson, S. (1991). The development of middle school teachers content knowledge and pedagogical content knowledge of heat energy and temperature. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Leinhardt, G., & Greeno, J. G. (1986). The cognitive skill of teaching. Journal of Educational Psychology, 78, 75-95.

Neely, A. (1986). Planning and problem solving in teacher education. Journal of Teacher Education, 37(3), 29-33.

Sanford, J. (1987). Management of science classroom tasks and effects on students' learning opportunities. Journal of Research in Science Teaching, 24, 249-266.

Schön, D. (1983). The reflective practitioner. NY: Basic Books.

Shulman, L. S. (1986a). Paradigms and research programs in the study of teaching: A contemporary perspective. In M. Wittrock (Ed.), Handbook of Research on Teaching (3rd ed.), (pp. 3-36). NY: Macmillan.

Shulman, L. S. (1986b). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 56, 1-22.

Smith, C., & Neale, D. C. (1989). The construction of subject matter knowledge in primary science teaching. Teaching and Teacher Education, 5(1), 1-20.

Wilson, S. M., Shulman, L. S., & Richert, A. E. (1987). "150 different ways" of knowing: Representations of knowledge in teaching. In J. Calderhead (Ed.), Exploring teachers' thinking (pp. 104-124). London: Cassell Educational Limited.

Woolfolk, A. E. (1989). Research perspectives on the graduate preparation of teachers. NJ: Prentice Hall.

Zeichner, K. M., & Liston, D. P. (1987). Teaching student teachers to reflect. Harvard Educational Review, 57, 23-48.

Chapter 4

How Teachers Translate Learning Theory into Instruction: A Study of Group Problem Solving by Prospective Secondary Science Teachers

Deborah J. Tippins
Dona M. Kagan
David F. Jackson

There is remarkably little empirical research examining how teachers understand and interpret the content of education courses, particularly courses that deal with educational learning theories (Peterson, Clark & Dickson, 1990). Two previous studies (Kagan, 1991; Pinnegar & Carter, 1990) have addressed learning theories.

Pinnegar and Carter (1990) compared the content of three popular educational psychology textbooks to the content of interviews conducted with cooperating teachers, who were asked to describe how they explained their classroom practices to student teachers. Although the science teachers and the textbooks often alluded to the same theories (in substance, if not in name) and included applications, the science teachers' explanations of theory varied in several different ways. First, the teachers (as opposed to the textbooks) tended to focus their discussions around the theme of student-teacher relationships as the heart of classroom learning. They also emphasized the role played by a teacher's intuition in establishing trust and confidence among pupils. Teachers appeared to understand theory only in relation to particular classroom experiences. Theory in the textbooks, by contrast, was presented as the more abstract and general product of academic discipline of educational psychology. Pinnegar and Carter concluded that teachers' understandings of theory, like the other kinds of professional knowledge they acquire, were mediated by their subjective experiences and personal epistemologies.

Kagan (1991) examined teachers' assumptions regarding the relevance to classroom practice of the kind of formal learning theory one encounters in educational psychology courses. The subjects were prospective teachers who wrote narratives explaining how knowledge of behavioral learning theory could help teachers resolve the problems described in open-ended case studies. The analysis indicated that both prospective and practicing teachers regarded formal learning theory as a "band-aid" that could be applied uniformly to any classroom context to yield predictable results. Practicing teachers appeared to be more sensitive to background variables and ethical dimensions inherent in a case than did prospective teachers.

In regard to teachers' views on foundational courses on the philosophy or history of education, the vast majority of studies have been limited by an exclusively self-report methodology; that is, researchers have employed attitude scales that asked teachers to rate the "importance" of foundations courses to their careers (e.g., American Association of Colleges of Teacher Education, 1987; Birkel, 1983; Sirotnik, 1990). Such studies provide no insight into how teachers make sense of foundations coursework or translate their content into classroom practice.

A single exception to this research tradition is a recent study conducted by McDaniel (1991) who used qualitative methods to examine how prospective candidates made sense of the content of a social foundations course. McDaniel found that students related the content to their own beliefs about good teaching and to their own experiences as teachers and students in classrooms. Thus, McDaniel's results, like Pinnegar and Carter's (1990), confirmed a growing body of research testifying that teachers—even teacher candidates—"filter" information through their personal belief systems (e.g., Berliner, 1987; Carter & Doyle, 1989).

Studies of prospective teachers have shown consistently that candidates enter teacher education programs with well-established beliefs about students, teachers, and classrooms (Book, Byers & Freeman, 1983; Feiman-Nemser, McDiarmid, Melnick & Parker, 1988; Guyton & McIntyre, 1990). A likely source of these preconceptions is the thousands of hours that teacher candidates have spent in classrooms as students, effectively internalizing models of good and poor teaching (Feiman-Nemser & Buchmann, 1985; Zeichner, Tabachnick & Densmore, 1987).

PURPOSE

The purpose of this study was to examine how prospective science teachers understood particular learning theories, not in abstract terms, but in terms of concrete classroom applications. That is, instead of asking people to explain the applications of particular learning theories, we asked them to design a lesson based on a learning theory. We used this strategy, as we were mindful of curriculum development theory—particularly Schwab's (1978) observation that people need a real context and real choices in order to realize and manifest their subjective biases and beliefs about curriculum.

We borrowed from curriculum development theory in a second regard; we perceived the task of designing a lesson for a particular content and grade level as a simplified task of curriculum development. The meetings during which the prospective science teachers planned these lessons were audiotaped. We equated their group discussions with curriculum deliberation, one of the three elements in Walker's (1978) naturalistic model of curriculum development.

According to Walker's model, curriculum development includes three elements: a curriculum platform, its design, and the deliberation process associated with them. Platform refers to the system of beliefs and values that developers bring with them to the task. This includes their conceptions (beliefs about what exists and is possible), their theories (beliefs about what is true), and their aims (beliefs about what is educationally desirable). Design refers to the set of abstract relationships embodied in the emergent curriculum. Deliberation consists of all of the dialogue involved in discussing the relevant facts, alternative solutions, and final choices. This was the element we attempted to capture on audiotape.

Curriculum deliberation begins with the formulation of a problem, which can be uncertain or procedural (Knitter, 1985). As these terms suggest, an uncertain problem requires initial value decisions to define the dilemma in concrete terms. A procedural problem focuses simply on methods of solution. For the prospective teachers who participated in this study, deliberation was simplified in that groups were provided with procedural problems.

We were particularly interested in examining the platforms that the prospective science teachers brought to the deliberation of the procedural problems. Recalling McDaniel's (1991) and Pinnegar and Carter's (1990) studies, we assumed that the teachers' pre-existing beliefs about classrooms and students would affect the interpretation of learning theories and the construction of lessons. Thus, group discussions would allow us to infer fundamental assumptions and preconceptions.

We also were interested in examining standard elements in the groups' deliberations. Case studies of genuine curriculum development have occasionally revealed patterns. For example, Hannay and Seller (1990), in a study of how Canadian teachers revised a high school geography curriculum, distinguished three stages in the deliberation process: cut and paste, when the teachers tried to piece together a new curriculum from the old one; cognitive dissonance, when they grew dissatisfied with the status quo and began to see the need for a totally new vision of teaching; and assimilation, where they created new images of teaching and learning in the form of a new curriculum. Would similar phases appear in the deliberations of the prospective teachers who participated in this study?

METHOD

Participants

Participants were 24 prospective teachers enrolled in a fifth-year masters degree program at a four-year, public university in the southeastern United States. All were enrolled in a course on teaching science to special needs students taught by one of the authors. All sought certification in science at the secondary level.

Procedures

The course, although oriented to classroom practice, used a learning theory, constructivism (Tobin, in press), as a theoretical foundation. The prospective teachers were introduced to constructivist learning theory through readings, class discussions, videotapes and guest speakers.

As a part of the course, the prospective science teachers were required to design a lesson based on constructivism and suitable for middle or high school science. They worked in four-member groups that were given two one-hour blocks in which to plan a lesson. Each group was required to present its lesson to the rest of the class, with each member assuming a particular role: one member presented an overview of the lesson, one explained its connections to the learning theory (constructivism), and one taught the first 15 minutes of the lesson. The fourth member of each group served as a secretary, observing the group's deliberations and preparing a written report.

Small-group work is an ideal setting for gathering data on problem-solving processes in a naturalistic mode, because in such a setting pertinent statements and questions about the task are frequently voiced by group members as a matter of course (cf. Schoenfeld, 1982), rather than being drawn out in a more artificial manner by a researcher's questioning or prompting. The participants were aware that their discussions were being audiotaped for later transcription. In a further effort to make participants comfortable with the process, the lessons that were planned and presented were not formally evaluated by letter grades.

Data Analysis

The authors independently evaluated the transcripts of all planning sessions. We read each of the transcripts first to gain an overall familiarity with their contents, then again to take detailed notes, and a third time to summarize each planning session in global terms. This involved the preparation of charts noting elements that were present in all of the transcripts, differences that were manifest between the transcripts, and short summaries of each planning session. Finally, we compared and merged the charts and summaries. The patterns that emerged are described in the following section.

RESULTS

Issues and Concerns

We identified several categories of issues and concerns addressed by the prospective science teachers during their planning sessions. These are illustrated in the following sample outline of a planning session, illustrated with excerpts from a transcript of the session (**K**, **R**, and **S** represent initials of the anonymous participants):

Explicit Reference to Theory

Recall that the assigned task was to construct a lesson "based on" constructivist theory. These prospective science teachers consistently operationalized this by extensively reviewing or clarifying their understanding of constructivism, implying a central role for explicit theory. Every transcript began with an extensive discussion and clarification of ideas associated with constructivism. In most cases, group members argued about aspects of the theory and its implications and spent a major portion of the planning session negotiating consensus in relation to the theory.

K: I understand [constructivism] as the opposite of reductionism, which is pretty much the way we were all taught. You know, the teacher gets up in front of the room and lectures or asks factual questions which have only one right answer. Students' answers are viewed as right or wrong, and there's no room for your personal interpretation. In constructivism, you can learn from your mistakes and try to defend what you think. Constructivism means taking the whole picture, where reductionism means you learn little bits and pieces and then move on to the next thing.

R: I don't think it's as simple as opposites. But what is important is that it's the student's responsibility to learn, and the teacher acts as a guide.

S: So it's really important to know where your students are coming from—what they've learned in past years both in and out of school.

R: I think you should use a lot of experiences that kids have in their everyday lives.

K: So then the teacher is more of a guide and a motivator, to stimulate students to discuss things among themselves and encourage students to question things and not always take them for granted.

S: How are we going to teach like this?

R: I think we should set something up for the students—a problem or something that they need to decide—something that will cause dissonance.

K: To show them an example of something and let them decide how and what should be done—like a problem to solve of some sort.

S: Then let them discuss it, and the teacher guides them with helpful hints along the way.

R: I think we could have a demonstration, but we should also have groups. That's the social part of constructivism—where kids feel like they have the freedom to test their ideas in the group setting.

Activity

The group identifies an activity or demonstration that will be the focal point of the lesson. It is usually something one or more of the group members saw or read about.

K: I saw a demonstration with a water wheel at a seminar that I was at that really provides opportunities for problem solving. I'm not sure if I can figure out how to set it up, but I could get in touch with the guy if we can't figure out how to set it up.

Sequence

The central activity or demonstration is elaborated in terms of a sequence of actions to be performed by the teacher. At this point, student responses were not yet considered.

R: How does it work?

K: You know how Archimedes' Principle works—it's like the law of siphons. He had this box, and it's a water-producing machine, and he pours water in the top. It's a box, just a cardboard box, and the back is out. So you have top, bottom and sides. Now you see the front of this box, and up here is has a funnel going in. Down here is a hose with a hole coming out. Up here he pours water, and he puts a beaker down here to catch it. He pours in 100 ml and 500 ml comes out. If there's a drop in the hose, the pressure siphons out more water than he puts in.

Objectives

Having identified and described a central activity, and perhaps spelled it out, the group considers what learning objectives would be accomplished in the lesson—What specific skills or concepts would be taught via the sequence of activities? Sometimes this involves a discussion of the appropriate grade level for the lesson, and whether the concepts would be too difficult or too easy.

S: What's the principle behind that?

K: It's suction.

S: Would that be cohesion?

K: Yes, it would be cohesion and adhesion.

Clarifying Content Matter

Here group members discuss the academic concepts that are being taught via the sequence of activities. Occasionally, this is a matter of simply reminding themselves of the point of the activity. More often than not, however, the discussion component involves issues of pedagogical content knowledge. Sometimes this reveals real puzzlement in that one or more group members are not sure about some concept in physics, math, etc. and how best to teach it. In effect, the group members themselves are constructing knowledge about (making sense out of) the activity that has been targeted.

S: Yes, cohesion because the water sticks together. If the water comes up then more water is going to come up, because ten water molecules are sticking together. Because it's not really pressure.

R: No, but pressure starts it.

K: Pressure is the initiator. Pressure is the enzyme, so to speak.

R: And it has to do with the drop. There has to be a certain drop. What has the drop got to do with anything?

K: It might have to do with kinetic and potential energy.

R: Potential and kinetic energy transfer.

K: There are a lot of things involved. We can come up with a few and get the class to come up with more.

Curriculum Sequencing and Students' Prior Knowledge/ Preconceptions

The group discusses the role of preconceptions including implicit reference to constructivist concerns.

S: There are really a string of concepts involved. Do we want to assume that students have prior knowledge of some of the concepts?

K: Let's say that they already have an understanding of potential and kinetic energy and Pascal's law of pressure. Should we give them any additional information?

R: Well, the idea is for them to generate a model that explains how the water wheel works. So even if we give some basic information, different group members will make sense of that information in various ways, depending on their experience. So different groups will probably have very different models.

K: Are we supposed to give them information or should they recall what they know from prior experience?

Dialogue

Teacher and student behavior is specified in terms of anticipated dialogue: i.e., *exactly* what the teacher would say to introduce the demonstration, what students' responses are likely to be. In some transcripts, members speculate about misconceptions or errors that might occur in students' responses.

S: I think we can ask questions like, "when we raise the water, what kind of energy is that?" or "when you take something and move it from here to there, what is happening with the energy?" That's not really giving them information.

R: It's like an anticipatory set—the first thing that catches their eye is the water wheel, the problem. But should we do it the other way—give them enough information to help them frame the problem?

K: Maybe we should think about another activity. . . .

Reconsider theory

The group focuses on whether the lesson as planned reflects beliefs consistent with social constructivism

S: I think the water wheel fits in with the ideas of constructivism. Students can construct explanatory models. They have the opportunity to revise their models when they see what other groups do. They get to discuss and negotiate their understanding of the concepts involved. It may take longer this way, but. . . .

R: It also goes well with constructivism, because it involves cooperation and first-hand experience.

Audio-Visual Aids and Manipulatives

The sequence of activities is further spelled out in terms of specific audio-visual aides. Manipulatives that the students would handle, as well as transparencies, posters, and charts are often described.

K: OK, so let's list the materials we will need and then plan a time when we can get together to build the water wheel.

Relationship of Theory and Practice

In the sample outline above, the pervasiveness of theory in these prospective science teachers' planning can be seen very clearly. Issues of science content and of specific pedagogical techniques are discussed, but the conversation always returns to the issue of consistency with constructivist theory, which ultimately seems to take precedence over all more mundane practical considerations.

As evidenced by their group discussions, all of the prospective science teachers learned the theory of constructivism very well and took it seriously as a guide in their planning processes. They did not spend much time talking about how to operationalize a lesson, in terms of tying into specific learning/curricular objectives, and elaborating it in terms of steps. The groups rarely put verbatim dialogue in their plans and did not translate the science lesson into a series of activities.

Their planning appeared to mirror the instructor's holistic, constructivist approach. Thus, planning emphasized the exploratory nature of an activity. Prospective science teachers debated and discussed why some phenomena were occurring and how best to help students construct an understanding of the phenomena. Their lessons were totally student-centered, with the teacher in the role of a facilitator. They struggled with the problem of how much information the teacher can provide without making the lesson a teacher-centered dissemination of "knowledge." Some groups resolved this dilemma by sidestepping it, claiming that the class had already learned the material in prior days.

The groups discussed the way in which constructivism was tied to the culture of the classroom, emphasizing the social aspects of sense-making. They never attempted to see the lesson in terms of fitting into a specific curriculum. Rather, they planned and discussed it in terms of the idea of multiple curricula and the context in which teaching would take place.

DISCUSSION AND IMPLICATIONS FOR TEACHER EDUCATION

Previous studies have found few teachers who exhibited evidence of intentional application of theory to the instructional planning process (Harste, 1985; Richardson & Hamilton, 1988). Rather, teachers appear to use learning theories in instructional planning only as an afterthought. Sosniak, Ethington and Varelas (1991) also indicated that practicing teachers do not adhere to curriculum that comes from some consistent theory of learning/teaching. Their data from the Second International Mathematics Study indicated that mathematics teachers apparently hold positions about the aims of instruction, role of the teachers, nature of learning and nature of mathematical subject matter that seem to be logically incompatible, and teach their subject matter without a theoretically coherent point of view. The planning groups in this study, in contrast, used coherent theory explicitly as they planned their lessons.

Contrary to what prospective teachers are often taught in their education coursework, most practicing teachers do not plan instruction linearly in terms of objectives. Instead, they appear to follow an "agenda-formulation" model of planning; they construct lessons by combining discrete activities that have worked for them in the past (Blumenfeld, Mergendoller & Swarthout, 1987; Clark & Yinger, 1987; Zumwalt, 1989), or they use "key activity structures" as vehicles to translate their beliefs into classroom practice (Bromme & Juhl, 1988; Brown, 1988; Hollingsworth, 1989). Such structures and models did not seem to play a major role in the planning process of the prospective teachers in this study, perhaps because they had little or no previous practical teaching experience behind them.

Prospective science teachers, at this stage, have few of their own resources and teaching experiences to draw on. They rely substantially on what they see modeled by their instructors, i.e., how they perceive that the instructors present and use theory. This can both enable and limit them tremendously; thus, instructors must strive to be aware of the practical message that their theoretical perspective is effectively sending.

The objectives/goals of a teacher education program can play a critical role in determining the capabilities of prospective teachers (Lanier & Little, 1986). Stoiber (1991) compared a technical versus a reflective/constructivist approach to teaching classroom management strategies. Different treatments yielded students who were capable of doing different things. In this study, the emphasis on a reflective/constructivist approach seems to have had a significant influence on the groups' planning processes and associated end products.

An important implication of this study is the need for teacher educators, including science teacher educators, to clarify the relationship between theory and practice. King & Young (1986) describe different forms that can be used to logically structure the relationship between theory and practice, including both control models and communication models. When control models are used to structure the relationship between theory and practice, "the capacity to bring about a desired result is dependent upon finding a condition which it is in your power to manipulate." (p. 28). Communication models, in contrast, rely on persuasion, "a communicative method which depends upon 'activating' the thoughts and feelings of those with whom you are communicating" (p. 28). This emphasis on interpersonal relations can contribute to a productive creative process by facilitating a dialogue in which theory and practice are very closely linked and mutually relevant, known as "reflexive theorizing":

> ...reflexive theorizing...can avoid the kind of total gap between theory and practice that often occurs...due to the separation in actual time and space of law and manipulation of conditions, message and understanding. This difference arises out of the fact that, under certain conditions, reflection on the historical formation of social relations, and in an intertwined way, on the biographical formulation of our selves within that network of relations, becomes, simultaneously, both theory and practice. (King & Young, 1986, p. 32)

The complementary notions of a communicative method and reflexive theorizing were the theoretical lens through which the instructor in this course viewed the relationship between theory and practice.

Encouraging prospective science teachers to combine theory and practice in this way in their pedagogical coursework should be only the beginning of a better-integrated process of teacher education. When prospective science teachers move on to clinical experiences, they very often must deal with apparent contradictions between the theoretical positions espoused by education faculty and the habits and rules of practice urged on them by cooperating science teachers, with whom they spend a majority of their time. During student teaching in particular, this can sometimes lead to a cynical duality between their planning for "normal" days versus the relatively few days on which they expect to be directly observed by their supervisor. In order to implement a communication model of theory and practice and facilitate reflexive theorizing, two major changes must be made in the most common current state of affairs: first, cooperating science teachers must come to value learning theories as a useful heuristic device in their own planning processes; second, science teacher education faculty must enter into an extended, ongoing dialogue with both prospective and cooperating science teachers throughout the full extent and range of clinical experiences.

REFERENCES

American Association of Colleges of Teacher Education. (1987). *Teaching teachers: Facts and figures.* Washington, DC.

Berliner, D. C. (1987). Knowledge is power: A talk to teachers about a revolution in the teaching profession. In D. C. Berliner, & B. W. Rosenshine (Eds.), *Talks to Teachers* (pp. 3-33). New York: Random House.

Birkel, L. F. (1983). How students view foundational studies in education. *Action in Teacher Education, 5*, 79-87.

Blumenfeld, D. C., Mergendoller, T. R., & Swarthout, D. W. (1987). Task as a heuristic for understanding student learning and motivation. *Journal of Curriculum Studies, 19*, 135-148.

Book, C., Byers, J., & Freeman, D. (1983). Student expectations and teacher education tradition with which we can and cannot live. *Journal of Teacher Education, 34*(1), 9-13.

Bromme, R., & Juhl, K. (1988). How teachers construct pupil understanding of tasks in mathematics: Relating the content to cognitive processes of the learner. *Journal of Curriculum Studies, 20*(3), 269-275.

Brown, D. S. (1988). Twelve middle-school teachers' planning. *The Elementary School Journal, 89*, 69-87.

Carter, K., & Doyle, W. (1989). Classroom research as a resource for the graduate preparation of teachers. In A. Woolfolk (Ed.), *The graduate preparation of teachers* (pp. 51-60). New York: Prentice-Hall.

Clark, C. M., & Yinger, R. J. (1987). Teacher planning. In D. C. Berliner, & B. V. Rosenshine (Eds.), *Talks to teachers* (pp. 342-365). New York: Random House.

Feiman-Nemser, S., & Buchmann, M. (1985). Pitfalls of experience in teacher preparation. *Teachers College Record, 87*, 49-65.

Feiman-Nemser, S., McDiarmid, G. W., Melnick, S., & Parker, M. (1988). *Changing beginning teachers' conceptions: A study of an introductory education course.* East Lansing, MI: National Center for Research on Teacher Education, Michigan State University.

Guyton, E., & McIntyre, D. J. (1990). Student teaching and school experience. In W. R. Houston (Ed.), *Handbook of Research on Teacher Education* (pp. 514-534). New York: Macmillan.

Hannay, L., & Seller, W. (1990). The influence of teachers' thinking on curriculum development decisions. In C. Day, M. Pople, & P. Denicolo (Eds.), *Insights into Teachers' Thinking and Practice* (pp. 240-258). London: Falmer Press.

Harste, J. C. (1985). Portrait of a new paradigm: Reading comprehension research. In A. Crismore (Ed.), *Landscapes: A state-of-the-art assessment of reading comprehension research, 1974-1984* (pp. 1-24). Bloomington, IN: Indiana University Press.

Hollingsworth, S. (1989). Prior beliefs and cognitive change in learning to teach. *American Educational Research Journal, 26*, 160-189.

Kagan, D. M. (1991). Narrative semiotics and teachers' beliefs regarding the relevance of formal learning theory to classroom practice. *Journal of Educational Psychology* (in press).

King, R. R., & Young, R. E. (1986). *A systematic sociology of Australian education*. Sydney: Allen & Unwin Australia.

Knitter, W. (1985). Curriculum deliberation: Pluralism and the practical. *Journal of Curriculum Studies, 17*, 385-95.

Lanier, J., & Little, J. (1986). Research on teacher education. In W. R. Houston (Ed.), *Handbook of Research in Teacher Education* (pp. 527-569). New York: Macmillan.

McDaniel, J. E. (1991, April). *Close encounters: How do student teachers make sense of the social foundations?* Paper presented at the annual meeting of the American Educational Research Association, Chicago, Illinois.

Peterson, P. L., Clark, C. M., & Dickson, W. P. (1990). Educational psychology as a foundation in teacher education: Reforming an old notion. *Teachers College Record, 91*, 322-346.

Pinnegar, S., & Carter, K. (1990). Comparing theories from textbooks and practicing teachers. *Journal of Teacher Education, 41*(1), 20-27.

Richardson, V., & Hamilton, M. L. (1988, April). *Teachers' theories of reading*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans.

Schwab, J. J. (1978). The practical: A language for curriculum. In I. Westbury, & N. J. Wilkof (Eds.), *Science, curriculum and liberal education: Selected essays of Joseph J. Schwab* (pp. 287-288). Chicago: University of Chicago Press.

Schoenfeld, A. H. (1982, March). *On the analysis of two-person problem-solving protocols*. Paper presented at the annual meeting of the American Educational Research Association, New York. (ERIC Document Reproduction Service No. ED 219 434)

Sirotnik, K. A. (1990). On the eroding foundations of teacher education. *Phi Delta Kappan, 71*(9), 710-722.

Sosniak, L. A., Ethington, C. A., & Varelas, M. (1991). Teaching mathematics without a coherent point of view. *Journal of Curriculum Studies, 23*, 119-131.

Stoiber, K. C. (1991). The effect of technical and reflective preservice instruction on pedagogical reasoning and problem solving. *Journal of Teacher Education, 42*(2), 131-139.

Tobin, K. (Ed.) (in press). *Constructivism and the teaching and learning of science and mathematics*. Washington, DC: American Association for the Advancement of Science.

Walker, D. (1978). A naturalistic model for curriculum development. In J. Gress, & D. Purpel (Eds.), *Curriculum: An introduction to the field*. Berkeley, CA: McCutchan.

Zeichner, K. M., Tabachnick, B. R., & Densmore, K. (1987). Individual, institutional, and cultural influences on the development of teachers' craft knowledge. In J. Calderhead (Ed.), *Exploring teachers' thinking* (pp. 21-59). London: Cassell.

Zumwalt, K. (1989). Beginning professional teachers: The need for a curricular vision of teaching. In M. C. Reynolds (Ed.), *Knowledge base for the beginning teacher* (pp. 173-184). New York: Pergamon.

Chapter 5

Becoming a Reflective Science Teacher: An Exemplary Endeavor by a Preservice Elementary Teacher

Anita Roychoudhury
Wolff-Michael Roth
Judy Ebbing

In the past decade there has been an upsurge in the number of teacher education programs that encouraged reflective practice by prospective teachers (Gore & Zeichner, 1991). However, teacher educators define reflective practice in various ways (Kottkamp, 1990). We believe with Schön (1983, 1987) that reflective practice is grounded in learning from one's own experience through a process of deliberation. However, a large number of the programs that have a reflective component are guided by a technical rationality that dichotomizes a problem and its solution (Gore, 1987; Kottkamp, 1990). In this view, reflective practice often comprises adjusting means to best fit the ends or mastering a certain technique.

The participants in professional education programs appear to deal with well-defined problems rather than with uncertainties of real-life. They are guided by the dominant technical rational premise of professional education. Schön (1983, 1987) challenged this premise in his seminal works. He argued that more attention needs to be paid to the "artistry" of a profession by incorporating reflection-in-action and on-action in the practicum experiences. Reflection-in-action constitutes an integral part of the knowledge of a profession and occurs when a practitioner faces events that elude the ordinary categories of knowledge. In actual practice,

> (p)roblems do not present themselves to the practitioner as givens. They must be constructed from the materials or the problematic situations that are puzzling, troubling, and uncertain. When we set the problem we select what we will treat as the "things" of the situation, we set the boundaries of our attention to it, and we impose upon it a coherence which allows us to say what is wrong and in what directions the situation needs to be changed. (Schön, 1983, p.40)

The act of *setting* or *reframing* a problem to make a complex situation manageable is at the heart of reflection-in-action. This non-logical and dialectical form of reflection intricately mingles problem setting with problem solving. Here, solving a problem depends on "seeing a problem differently" (Russell & Munby, 1991). Reflection is also involved in post hoc thinking and deliberation of the information available in order to arrive at a solution. This, according to Schön (1983), is reflection-on-action, which deals with a well-defined problem and is characterized by a means-to-end underpinning.

Practitioners in any field develop a certain form of knowledge through reflective activities. The knowledge-of-practice, thus developed, is tacit and becomes an integral part of one's repertoire of expertise. This is what is considered as the artistry of a profession. Aspiring practitioners need most to learn this artistry to deal with indeterminate situations in practice; yet, professional schools seem to be least able to teach this (Schön, 1987). The tacit knowledge of a profession cannot be taught; students have to develop it through experience, by immersion in actual practice, and by learning to reflect. A teaching practicum must be a part of teacher education, and therefore, needs to be reflective, providing opportunities to engage in reflection.

It is common knowledge among teacher educators that beginning teachers often find themselves overwhelmed with various constraints in their practice. It is unreasonable to expect that they will be able to solve their problems without having any experience to do so. Besides, the problems teachers face in classrooms are often ill-defined, uncertain, and unique, hence defy a solution through direct application of textbook knowledge. It is only through reflection and guidance that they can learn to recast classroom situations in the light of clarifying questions. The art of a practice entailed in dealing with unique situations lies in making sense of the problem by framing it in a way that renders it manageable (Schön, 1983, 1987). But such an experience is often lacking in teacher education programs, students rarely get any scope for making sense of complex situations.

Methods courses, where students learn to think about teaching as practice, are guided by a means-end view of teaching and learning. Adler and Goodman (1986) view methods courses as too idealistic and theoretical, failing to provide students with valuable relevant experiences. In teacher preparation programs, preservice teachers generally get a chance to gain a first-hand experience with teaching and other classroom practices during their student teaching semester. But student teaching experience is placed at the end of their university career, when many students find competing demands on their time (McCarthy, 1986) with little scope for deliberation on uncertain situations. Practicum essentially becomes the first exposure to the real world of teaching. But merely exposing students to a teaching-learning milieu is unlikely to enhance their knowledge of practice (Goodman, 1986). Experience without reflection on that experience is insufficient for learning. Neophyte teachers are unlikely to grow into full professionals unless they learn to reflect on how theory fits into their personal experiences.

"(P)ersonal experience that is reflected on and examined, in order to derive ways to improve one's own performance, is a very valuable teacher" (Berliner, 1987). Particularly for those who have limited exposure to a profession, such as beginning teachers, experience accompanied by reflection is perhaps the best teacher. Even when teacher education programs incorporate a reflective approach, however, they are mostly guided by a technical rationality; rarely do they focus on guiding students to set a problem by defining the boundaries of a complex situation.

One major implication of the foregoing discussion is that teacher education programs need to expose preservice teachers to the real-life classroom situations that enable them to realize some of the potential problems and to engage in reflective practice. However, the tacit knowledge that may develop through the process of problem setting will not enhance the experience of novices unless that knowledge is made explicit. Teacher educators need to help preservice teachers make the learning that remains tacit in their experience explicit. Such practice will enable beginning teachers to answer some the most pertinent and puzzling questions they face; questions such as, "How do I know what I know? How do I know the reasons for what I do? Why do I ask my students to perform or think in particular ways?" (Shulman, 1988). However, to render tacit knowledge explicit requires reflection-on-action. It involves a retrospective analysis of the means and the end. Hence, Shulman argued that the technical rationality underlying the process cannot be discarded altogether. Rather, a reflective practicum needs to incorporate a merger of the two perspectives, namely the artistry inherent in the tacit knowing from experience and technical rationality entailed in making the tacit explicit. We do not deny the technical view underlying the analysis of a problematic situation and its solution. At the same time, we believe that if such an analysis informs practice and becomes part of an ongoing process of guiding prospective actions on the basis of retrospective knowledge it transcends the demarcation between theory and practice and establishes a dialectical relationship between the two (Carr & Kemmis, 1986).

The significance of classroom experience for becoming a reflective practitioner is rendered salient in the study reported by Russell and Munby (1991). They presented cases of reflective practice by expert teachers in their daily teaching. The beginning teachers involved in the study exhibited limited ability to display knowing-in-action in their teaching. It seems that part of the problems of these novices hinge on their lack of experience with reflective practice. In order to improve the preparation of future teachers, the practicum needs to become an insightful experience.

The preparation program of the preservice teachers should help them reflect upon the practice, and engage in self-monitoring habits. These habits are essential (a) to help beginning teachers in their trajectory from peripheral participation in teaching during practicum experiences to core practice as full teachers, (b) to facilitate teachers' learning from experience, and (c) to help teachers improve teaching throughout their careers (Biott, 1983; Rudduck, 1985). Thus, evidence of future teaching performance of student teachers would be a propensity to reflect upon their practice (MacKinnon & Erickson, 1988).

An action research approach is appropriate for incorporating reflection in practica because it allows the participant to undertake inquiry to understand and improve practice (McCutcheon & Jung, 1990). Central to our approach is the belief that a reflective practice needs to be guided by the problems of interest to the participating beginning teacher who experiences the problem, rather than by an outside expert, who identifies and poses a problem. One approach would be to let preservice teachers identify situations they consider problematic and then help them construct and reframe their problems to render them manageable. On the other hand, if reflection becomes just another requirement to be fulfilled, or the problem is selected by the supervisor, the relevance of the endeavor for the student will be lost. They will likely resist the demands of reflective practice that does not promise immediate practical utility (Schön, 1987).

In this chapter we focus on two cases from Judy's reflective experience. The first case illustrates the reflection-in-action. Through a narrative we depict how Judy reframed a problem she perceived regarding science instruction at the elementary school level and thereby constructed a solution. The second case is a description of Judy's reflection-on-action, which helped her explicate what she learned from her practice. We would like to underscore here that this study did not adopt a recipe-driven approach in which students mechanically apply the steps in the action research spiral. We also took care to avoid reflection as an end in itself or as a purely individual activity disconnected from the actual practice (Gore & Zeichner, 1991).

RESEARCH DESIGN

Participants

Judy is a preservice elementary teacher, whose reflective practice about science instruction is the focus of this study. During the study she was in the junior year of her program. She joined the undergraduate program in elementary education at a midwestern university after a ten-year gap in her academic career. Due to her interest in teaching and learning science, she opted for a science concentration within the elementary education program. She is a level-headed, sincere and caring person. Through a collaborative effort between a midwestern university and a local school system, Judy became an intern at a school. Here she worked for one year, three hours daily, in a second grade classroom. Judy helped the regular teacher in planning, teaching, and grading. Either alone or with the senior author (AR), she observed and reflected on the teaching and learning in different classrooms.

During the time of the study Judy and the senior author were on their third semester of course work together. The climate of trust that had developed through this long-standing relationship was conducive to nurturing reflection in a risk-free environment. This trust made the joint reflection sessions smooth, informal, and personal, focusing on Judy's concerns. The second author (WMR) engaged with the first author in extensive discussions of the findings, conclusions, and tentative analyses of the data. He took the role of a "disinterested peer" (Guba & Lincoln, 1989). The purpose of a disinterested peer is (a) to help the local participants in a research project to make explicit the tacit and implicit information that they possess and (b) to "test out" the participants' constructions with someone who does not have contractual interest in the situation (Guba & Lincoln, 1989).

Classrooms Involved in the Study

There are 26 students in the second grade classroom where Judy is an intern. The students are primarily white and come from middle-class families. Carla, the classroom teacher has 10 years of experience in teaching and is highly esteemed as an efficient teacher by the principal of the school. She maintains a culture of discipline and order in her classroom. She attempts to follow the curriculum guidelines and the textbooks as closely as possible. The daily routine in her classroom generally consists of several 40 minute time blocks set for the teaching of various topics and subjects. Teaching-learning activities are teacher-centered and Carla attempts to be in control of the classroom environment. Carla teaches science twice a week, but only every other week, because she alternates it with health studies.

Judy and AR, together, observed two fifth grade classrooms. The primary difference between these two classrooms and Carla's classroom was the frequency and the nature of science instruction. Cindy and Nancy, the two fifth grade teachers, were both science enthusiasts and taught science everyday. They made modifications in the fifth grade curriculum to fit science in their daily routines. Their science lessons frequently incorporated hands-on activities, whereas science lessons in Carla's classroom were based on textbook and worksheets. Nevertheless, the culture of discipline and order, teacher-centered instruction, and strict adherence to the segmented daily routine were prevalent in both the fifth grade classrooms.

Data Collection

For the first six months of the internship Judy was also enrolled in science, language arts, and mathematics methods courses. During this period she kept a daily journal on her intern experience. After six months, we (Judy and AR) began the study of reflective practice, and this study continued for five months. To begin, we briefly discussed the concept of reflective practice and Judy agreed to include her thoughts along with her observations in the journal. Together we observed the fifth grade classrooms taught by Cindy and Nancy. Each classroom was observed once a week for four weeks. We discussed these observations as well as the relevant issues from Carla's classroom. Each of our discussions was audiotaped. In addition, Judy kept journals on her own teaching, the instructional milieu of the classroom where she taught, and the ones she visited. AR read her journals once a week and asked for elaboration, justification, or supporting evidence for the comments written therein to which Judy responded wherever warranted.

Data Sources

In addition to Judy's reflective journal, the data sources included (a) her lesson plans, (b) videotapes of her teaching, (c) AR's reflective notes on classroom observations, Judy's journal, her teaching, and conversations with the participants, and (d) transcripts of audiotaped conversations between Judy and AR.

Data Analyses

An interpretive research methodology was used to analyze the data (Erickson, 1986). The analyses were guided by the action research premise of the study. Thus, the roles of AR and WMR were to help Judy interpret the patterns emerging from her reflections. The findings presented in the next section emerged through our individual readings of various data sources, and many discussion sessions.

FINDINGS AND DISCUSSION

In the following sections we will present our findings in the form of two cases from Judy's reflective practice that constitute the focus of this study. The first case is a narrative about how Judy reframed her initial problem into a new problem. The second case is a description of how she made her tacit knowledge explicit.

Solving the Problem through Reframing

Initial Problem

Science is taught in a very discouraging way... There is too much to cover in the curriculum, hence the teacher's rush. (Judy's discussion with AR)

The above quote represents Judy's concern about the state of science teaching. As a science-enthusiast preservice teacher, she believes that science lessons hold great potential for arousing student interest in natural phenomena and things around us. Active participation of students during a lesson is the key factor for science to become meaningful to them. But her experience in the actual classroom stand in stark contrast with her beliefs.

Judy elaborately expressed her concern about the status of science teaching in her journal:

> Sometimes I get discouraged when I see how science is taught... Science is taught every two or three weeks (alternates with Social Studies or Health). It is the last subject of the day,

> which means it gets crammed in whatever time is left after completing the rest of the day's lessons. In fact, most of the time a science lesson is limited to 20 minutes of reading and doing a worksheet....It bothers me because science is everywhere. So much can be done with it.

Judy's experiences as an intern and as an observer in various classrooms were incompatible with her expectations as a future teacher. The classroom where she worked presented a situation that was quite contrary to her philosophy of student-centered teaching. She strongly believed that actively engaging students in learning is an important aspect of teaching. She viewed teachers as facilitators, who guided student learning. But according to her observations of the second grade classroom, little time was allowed for students to engage in the interactions that took place in classrooms. The teacher was more concerned with covering the material; as a result, productive learning had to be sacrificed often.

In order to expand Judy's experience with observations on different types of science instructions, we (Judy and AR) began attending the science lessons taught in two fifth grade classrooms in two different schools. The science lessons in these two classes were atypical of the pattern prevalent in the elementary grades. Cindy and Nancy were science enthusiasts and taught science everyday. On the surface, their instruction frequently incorporated many desirable features, such as demonstrations, filmstrip showing, and hands-on activities. Nancy often blended other subject areas with science, whereas Cindy did not. After observing a lesson on density in Cindy's class, Judy remarked during our discussion session:

> I think Cindy (the fifth grade teacher) was trying to do an awful lot in a very very short time. I thought she was trying to form concepts and generalizations,—a lot of them, in a very short amount of time. I would take one thing; for example, she was pouring liquids of various densities in the cylinder, the heaviest, then the next heaviest and so on. I will let the kids try it in any order and in any combination they want, see what happens, and then discuss with them. I understand the pressure of the curriculum. You got to get all that stuff into the year and it is almost impossible.
>
> . . . It really bothers me to see the teacher rushing through materials without having the time to consider where the students are, in terms of understanding. I would like to teach a smaller number of topics or concepts and teach them well, by allowing time for activities that embody the concept and also for discussion.

This concern for covering the material appears repeatedly in Judy's initial journal entries and our conversations. It becomes a key issue in her thinking. Her concern about active participation of students and the related problem of the size of curriculum is well known to researchers of science education (Martens, 1992; Pratt, 1981). A higher degree of student participation in the instructional process seems to entail a smaller number of topics that can be taught. In science classes a potentially good demonstration or activity becomes just another vehicle for rote learning if the teacher focuses on covering the topics within a limited time rather than engaging students in a discussion of what they are observing or doing.

Although Judy's criticism of science instruction was legitimate, it was imperative that she attempt to view it from the perspective of a classroom teacher and not as an outsider evaluating a certain mode of instruction. She needed to think why teachers might be attempting to cover the curriculum the way it was prescribed. As a future teacher she needed to consider the possible consequences of not covering all the topics. Responding to the question "what will happen if a teacher does not cover the set curriculum?" Judy said:

If they do not cover the material then they keep that news to themselves. Not being able to complete the required topics is not something that teachers feel proud about. And I think school authority and the principals expect the teachers to teach whatever is there in the curriculum... They can teach any way they want to but the authority would expect them to cover the curriculum.

The above excerpt illustrates that Judy did not perceive that teaching only a few topics as a legitimate solution to her "too much to cover" problem. She needed to construct a solution that would be acceptable to the authority. Given the power structure of public school system, teachers are often constrained by authoritative evaluations by superordinates, such as a principal (Brickhouse and Bodner, 1992). In such cases, teachers would not take measures they perceived unacceptable to the school authority. It is very likely that teachers would tend to cover the curricula if they perceive that is what is expected by the authority. Judy initially thought that the solution to the problem was beyond the jurisdiction of teachers because they did not select the content of the curriculum. In her view, only principals, superintendents, or science coordinators could make curriculum choices; hence, it remained for the authority to reduce the content to help teachers improve teaching. Judy considered this problem out of her control; yet, it continued to bother her.

Reframing of the Problem

A new perspective about her concern for "too much to cover" took shape in her mind as she observed Carla, teach language. She wrote in her journal:

> Carla (the second grade teacher) is teaching about contractions during language time... (h)owever, she has already taught lessons on contractions in spelling. She could integrate these materials—she could eliminate unnecessary repetition and wasted learning time...

Here Judy looked at the problem as that of integration. However, she did not realize that by reframing she had constructed a solution to her own "too-much-to-cover" problem, at least within the language area. During a conversation on the day after this journal entry, Judy reiterated her idea about integrating topics and activities related to language thereby eliminating repetition. At this point Judy was convinced about her idea of integration but she had not thought of extending it across subject areas. She was not thinking about integrating science with language, social studies, or mathematics, the subjects that occupy larger blocks of time at the elementary level.

Reframed Problem

Judy's initial concern about "too many topics to be covered in a limited time" has now become "topics within a field need to be integrated for a better use of time.

The above assertion was constructed from Judy's journal entry, her reflections and her discussions with AR. Judy had begun to look at her concern in a different way through a dialectic process of observation/participation in the classroom and through reflection. Yet, her initial concerns about the lack of importance given to science instruction and student participation remained unattended. To overcome this situation, she needed to be aware of it as a participant-researcher in this project. The role of the co-researcher was to guide her reflection so that she could bring a coherence to the divergent situations arising from classroom contexts.

In an attempt to do so, AR inquired if Judy had found a way to deal with her "too much to cover" problem. Judy referred to her journal entry on Carla's lesson on contraction and indicated that integration could be done easily within language lessons. At this point however, she had yet to extend the concept of integration to subjects across the curriculum. The following vignette outlines Judy's trajectory to the problem resolution.

> During our subsequent observation of a fifth-grade science lesson, Judy asked Nancy how she managed to teach science everyday and whether or not she ever considered the amount of subject matter in a curriculum as a hindrance? Nancy explained that this problem did not exist for her because she integrated science with other subjects such as social studies, mathematics, and language. In this way she always found time to include science in the daily activities. Judy found Nancy's ideas interesting. In a subsequent journal entry Judy addressed the significance of Nancy's ideas.
>
> During our next meeting Judy's response to the "too much to cover" problem had changed. Earlier she held school authorities responsible for the curriculum. She now believed that teachers were to a large extent responsible for what happens in a

> classroom. Besides the school or district authorities, teachers also could bring about changes. The problem was not so much with what was listed in the curriculum guidelines but with the manner in which it was taught. Teachers needed to take the responsibility for rushing through the topics. The rush for time resulted from lack of teacher foresight, planning, and organization. They could integrate topics not within a subject area but across subject areas. Science could be integrated with other subjects.

The above vignette illustrates that Judy has now set the problem in a different way. Now she is asking herself how science could be integrated with other subjects. As a future classroom teacher, she plans to integrate science with other subjects as much as possible, although she is aware that it might be difficult, particularly during her first year. As a novice teacher she will have to learn many aspects of teaching-learning environment and take a great deal more responsibility than an intern or a student-teacher, but she hopes to learn from her experience.

Changing Practice

The changes of perspective that took place were not only confined to Judy's journal notes and our reflective conversations. They were apparent from the lessons she taught. Judy taught a reading lesson planned by Carla. This lesson was based on a story about a kangaroo. The classroom teacher's goal was to teach about the cause and effect relationships portrayed in the story and focus on some new words. Judy, however, saw a way to integrate science and social studies into the lesson by focusing both on the animal and on Australia without sacrificing the initial focus on language.

Toward the end of this study Judy was not concerned about lack of time in a classroom. Her new focus was effective integration of subjects to make time for science lessons and for student participation in the lessons. She had started collecting books and materials that could become resources when she became a classroom teacher. Her goal was to teach around themes and not "chopping time into so many minutes for reading, so many minutes for writing, so many for math."

Teachers' concern for time, integration of topics, or thematic teaching are familiar ideas to both experienced teachers and teacher educators; yet, they are rarely implemented in classroom teaching. Many experienced classroom teachers admit that doing activities in science is essential, that student participation is important; yet, they can not find time to incorporate these in their teaching (Roychoudhury & Heckman, 1992). In the light of veteran teachers' dilemma, Judy's story becomes significant as it hinges on a preservice teacher's approach toward the complex issue of time versus the volume of curricula. It is important to note that this is her first experience in teaching and observing a classroom from a future teacher's viewpoint. One can contend that the lack of experience is not crucial; a student should learn the idea of integration in method courses and be able to apply it in appropriate situations. However, the necessary connection between theory and practice often remains invisible to novice teachers, and their learning does not convert into practice (Lortie, 1975; Russell, Munby, Spafford & Johnston, 1988).

Beginning teachers often feel that they have been shortchanged during their academic experiences. What they have learned during various courses did not prepare them for their profession. We argue that the crux of real-classroom situations lies in their complexity and in the problem of turning knowledge-about-practice into knowledge-in-practice. The real-classroom situations are not clear-cut and do not easily fit within the scope of theoretical models. According to Schön's (1983, 1987) concept of epistemology of practice, problem solving in such cases becomes knowing what to do when one does not know what to do. Thus, the construction of a well-formed problem from an uncertain situation becomes a prerequisite to application of a theory. However, teaching practica rarely provide students with any such experience. Therefore, preservice teachers may not be able to define the boundaries of a problem and hence would not know how to apply their formal knowledge-about-practice. At the time of the study Judy had already taken several methods courses. Even if she had come across the idea of integration, she did not readily see any connection between that and the "too much to cover" problem. It is only through setting her new concern as that for a lack of integration did she construct a solution for the problem arising from the volume of a curriculum.

Making the Tacit Explicit

So often teachers talk to the class for hours, while so much can be done by letting kids **share** their ideas and having them discuss.

The above quote from Judy's reflection represents her concern about student-student interactions in a classroom. She further wrote about working with students in small groups and engaging them in discussions:

> Instead of the teacher talking all the time, students need to be given chances to discuss. I know initially, for example in the fall when I began having student share their ideas, I had difficulty in giving students the opportunity to share, to discuss their ideas. I would often lead the session as teacher-student, teacher-student, teacher-student type of interaction. But that's not sharing. That to me is recitation, low-level question answer session. Discussion to me is taking an idea and developing it, letting the student talk without any interjection from me. I am more comfortable with that now. I like to facilitate, not to direct.

This excerpt shows Judy's conviction that learning is enhanced when students share their ideas in small groups. It also illustrates her understanding of the distinction between discussion and other forms of interactions. In Carla's classroom, where Judy was an intern, students did not have any opportunity to share their ideas with each other. A considerable importance was given to individual learning pace thereby neglecting the social aspect of knowing. There were several learning centers featuring topics from science and other subjects where students performed their tasks individually. When students gathered in small groups with the teacher, the interactions were teacher-centered; students interacted with the teacher not with each other. This was at direct conflict with Judy's vision of teaching and learning.

With the permission of the classroom teacher Judy attempted to establish a culture of sharing. The activities she planned were based on the idea that discussion, cooperation, and interaction among the students facilitate learning. Owing to her inexperience, initially Judy had encountered some problems in implementing her ideas. We can get a glimpse of one of her dilemmas from the above excerpt. She realized that in her attempt to establish a culture of discussion among the students she was merely continuing a teacher-centered approach. However, over time she was able to establish an environment where students shared their ideas and they were in control of the discussions. Rather than focusing again on reframing, we will discuss how Judy made her tacit knowledge about sharing explicit. What was the premise of her faith in sharing? Why did she endeavor to establish this culture?

Initially, Judy's responses to the above-mentioned questions were vague. Although she did not know how, Judy believed that discussion and sharing ideas were conducive to learning; she valued the affective aspects of group learning:

> I really believe it (sharing) is important. I'm not sure why, except that I've seen that illustrated over and over and this year. That, when kids get to share something happens. Otherwise, they don't take as much ownership with the work, they don't take as much responsibility and when it's done it's out of their head. I think when they discuss and share, it has a lot to do with self concept, being able to express their ideas.
> ... I need to think about sharing more. I know it's important and I have reasons that I can not get out of a text book, but I need to think about it more.

It is apparent that Judy had an intuitive sense for the basic tenets of sharing, and she was aware that her textbook knowledge of cooperative learning did not engender this feeling; she learned it from her teaching experience. Her knowledge of group learning was implicit in her action. But she was not happy with her account, which only included the affective aspects of group learning. She felt that there were more important features that comprised her faith in this way of teaching. After further reflection she wrote a long note on the benefits of sharing and cited examples from activities and student interactions to substantiate her points. Because of her lack of familiarity with various forms of group learning, Judy did not distinguish between cooperative learning and sharing stories and ideas in small groups of six or seven students. Sharing, for her, could be working cooperatively on a project, reading one's report or story to a small group of students. She found the interactional aspects of the situation important. The following excerpts present a summary of her beliefs.

> I think cooperative learning helps students to develop social skills within the classroom. They learn how to cooperate to make group decisions, to form conclusions as a group, to find agreement.
> . . . I also like heterogeneous groups. There is less competition among the higher ability students. . . A few times we have had [in the classroom where she worked] heterogeneous groups, the higher achieving students were helping instead of competing and saying "well, I know this, I can do this. . . " They were more apt to help the person sitting next to them if that student didn't understand it. And the lower achieving students have less pressure, I think too, because it is their peers helping them and not their teacher pushing them.
> . . . Last fall I did an ice cube melting activity, where students had to form hypotheses in small groups and prove or disprove it. They had to reason about what they saw. They had to support their reasons for why they felt that way to form a group consensus. If a child could not give a reason to support an idea, the other kids didn't go along with it. For example, one student just said "I think it'll melt faster because it's on the teacher's desk" but he could not give a reason to support that, so the other kids did not accept it. Whereas, another student said "I think it'll melt faster in the sun, because the sun will make it warmer and it'll melt faster." That child had a good reason, so her hypothesis was accepted.

Judy revealed a clear understanding of some of the merits of group work. It also became apparent from the substantive examples that her knowing was embedded in her actions. The notable facet of her view on sharing was its similarity to the findings from various research studies on group learning. The development of social skills, support from peers in learning, the significance of a non-threatening environment for discussion, and the practice in justifying or elaborating one's own argument—all these features that Judy described—have been noted in the research literature (Brown & Palincsar, 1989; Cooper & Mueck, 1990; Johnson & Johnson, 1985; Roychoudhury & Roth, in press; Slavin, 1991). Judy's brief exposure to cooperative learning in her methods classes and her science content classes were instrumental in developing her faith in this mode. Nevertheless, because of her limited knowledge, her initial planning of the activities was simply based on belief and not on a theoretical model or on a step-by-step procedure. Her initial reflection revealed that she constructed for herself a rather loosely structured model of cooperative learning. She modified lesson plans as well as interactions according to her observations and reflections. In the course of teaching, Judy's faith in cooperative learning became stronger but the underpinnings of her belief remained tacit. Reflection on her ideas about sharing and on the process of translating those ideas into practice made her cognizant of the subtle underpinnings of her beliefs. As she continued to engage in the reflective practice, her tacit knowledge became progressively more explicit to her.

Schön (1987) claimed that reflection on one's own action plays an important role in acquisition of artistry. Through this process a practitioner can consolidate understanding and become more proficient in practice. In our study we observed how Judy's explication on group work enhanced her understanding and helped her devise solutions for problematic situations. During her reflection on the work of a particular group she realized that the absence of meaningful learning was related to the inequitable division of work. Some students carried the bulk of the tasks while others remained passive. Students did not know how to divide the work among the group members. Judy devised an alternative approach on the basis of her own science laboratory experiences, which involved group work. She decided to give students some structure about division of the tasks and thus hold individual members accountable. As the discussion on difficulties involved in group work evolved through our retrospective thinking toward the end of the academic year, Judy did not have the opportunity to try out her modified idea about division of tasks in group work. However, we believe that what she learned through reflection will be part of her repertoire of professional knowledge because this learning was situated in her personal experience.

In recent years many psychologists and cognitive scientists have come to the view that learning becomes meaningful when it is situated in context (Brown, Collins & Duguid, 1989; Collins, Brown & Newman, 1989; Rogoff & Lave, 1984). Learning is fostered when students are given the opportunity to actively construct ideas through their interaction with the environment. Based on our study, we believe that a similar rationale holds for the development of professional artistry. Judy's narratives on sharing and other experiences in her classroom were indicative of the situatedness of her knowledge. She was introduced to cooperative learning in her science methods course, and she had worked in groups in her science laboratory course. From these experiences she developed her liking for group work. But it was not clear to her why working in a group facilitated learning. What happens in a group that fosters learning? Why is it important to have students come to a consensus about a hypothesis or discuss the outcome of an experiment? She constructed her knowledge about these crucial facets through her own attempt to incorporate group work in her teaching and by interacting with the emergent constraints. She not only learned how to implement group learning but developed her own rationale for doing it.

Summary of Judy's Experience

During the course of this study, Judy identified two major concerns about science teaching. First, many teachers rush through subject matter without concern for student understanding. Second, teaching is primarily teacher-centered with minimal student engagement with each other. Gradually Judy learned to be a reflective teacher and to act in the indeterminate zones of practice, where situations are uncertain and not bound by the dichotomies of technical rationality. By explicating some of her tacit understandings of small group learning, she made that knowledge part of her professional expertise. She also became aware of how reflection was beneficial to her as a future teacher. In her last reflective note on sharing she expressed that this "backtalk" (Lanzara, 1991), this retrospective thinking made her aware of many indiscernible features of her own theory of sharing. During her retrospective reflections Judy also expressed that she considered reflection as a "form of experiment," as it guided her to try something new and look at a problem differently.

IMPLICATIONS FOR TEACHER EDUCATION

In this chapter we narrated the story of Judy's learning as she engaged in a reflective dialogue with her practice. Her experience illustrated that school is not a learning place only for the students but also for the teachers. One of the first things that beginning teachers learn is to find a viable match between their ideals for teaching and the demands of curriculum, classroom, and school environment. But in this process novice teachers may only learn to compromise with their ideals instead of achieving them (Brickhouse & Bodner, 1992). It is quite common for beginning teachers to be in situations that do not seem to be related to the knowledge they construct in their professional education courses. The tension between the theory that students learn in professional courses and its practice-relevance is familiar to educators as well as practitioners (Russell, Munby, Spafford & Johnston, 1988; Schön, 1983). Preservice teachers learn to apply theory to clear-cut problems. Most real-life situations, however, are complex, vague, inherently uncertain and may need to be set within the boundaries of some familiarity before they become manageable. Such reframing of events often entails a solution to the problem (Schön, 1983; Lave, 1988). It is essential that teacher education programs help future teachers learn to set a problem to be able to implement their ideas in the face of conflict.

Problem setting is one way professionals learn from their practice, but the knowledge generated through this process is often tacit. Making this tacit knowledge explicit enhances the experiential learning. However, the process of making tacit knowledge explicit requires the practitioner to reflect on action so that one knows why one does what one does. The reflection-on-action required to explicate the tacit knowledge implies that the process incorporates separation of means and ends as it is geared toward finding something standardized that can be applied in future situations. While accepting the dichotomy involved in such an attempt, we would like to underscore that the development of the knowledge about practice also includes knowledge about problem setting and knowing that practical problems are uncertain, complex, and often non-generalizable. The attempt to learn from experience entails a dialectic relationship between theory and practice. Thus, knowledge of practice cannot be premised only on the ground of technical rationality and cannot be viewed as comprised of rigors of selecting a solution for a well-formed problem.

The two aforementioned facets of professional knowledge, namely problem setting and making tacit knowledge explicit, still remain outside the scope of teaching practica. Preservice teachers do not have many opportunities to engage in either and thus lack a vital aspect of professional knowledge. Their experience remains incomplete and their knowledge consists of a dichotomized vision of the practice. Besides, it is unrealistic to expect that student-teachers will become reflective practitioners in the short course of their practicum. The vulnerability of preservice teachers during the practicum experiences is common knowledge for teacher educators. Teaching practica are the first time when they are to some extent in charge of classrooms. They have to make lesson plans, meet the demands of university requirements, classroom teachers' expectations and routines, classroom management, and numerous other unique situations. The experiences of a practicum can be confusing and even overwhelming. On the other hand, the competence to be learned in a practicum is complex and holistic. This competence cannot be taught by "telling" the students what to do (MacKinnon & Erickson, 1988). They must learn it for themselves with the help and guidance from an experienced practitioner. Thus, the process is bound to be slow and must include room for reflection and experimentation.

In the light of the above discussion, two features of this study become prominent. First, the span and the intensity of Judy's classroom experience. It is unlikely that she would have been able to engage in meaningful reflection, if she had to meet the typical demands of a practicum in a limited time. Second, this study was not directed by a recipe-driven approach toward action research. Judy was neither required to identify any problem nor solve it. During the study, she was only asked to elaborate or explicate her thoughts, which encouraged further reflection. In the course of the study, she devised her own way to deal with issues that were in conflict with her view of teaching. Her reflective practice emerged from her own experience-based concerns. Judy's learning implies that if students are required to reflect without having the opportunity to develop a genuine experience-based concern, reflection could become merely another task for practica. Thus, our study leads to a significant implication for teacher education programs. We believe that longer experience in classrooms as a part of practica is necessary for student teachers to become reflective practitioners. A step-by-step approach toward reflection is unlikely to foster the construction of appropriate knowledge-in-action. Conversely, increased length of the practicum by itself is unlikely to generate reflective practice.

Longer classroom experience and reflection need to be blended to make a practicum effective. The other essential criterion for a reflective teaching practicum is guidance and support. Reflection in isolation, without any opportunity for discussion with others—supervisors or peers—may end up as a futile endeavor. In the practical world of teacher education the nature of practica and mode of supervision may vary from one institution to other and even within the same institution. But the ratio of supervisors to student-teachers is not such as to make a one-to-one discussion similar to this study practical. We believe every educational situation can only be understood in the light of its own context; hence, we do not intend to generalize the findings of this study. We can only provide suggestions for teacher educators that need to be modified according to the needs of a particular context.

On the basis of our study, we suggest four basic features for a teacher education program that aims at helping future teachers to become reflective practitioners. First, learning to reflect requires time to develop; hence, reflection needs to be incorporated long before the practicum begins. Methods courses may be an appropriate place to incorporate reflection in teaching. Second, if the ratio of supervisors to student-teachers becomes a deterrent for arranging one-to-one discussion sessions similar to this study, group discussion sessions can be an appropriate alternative. Preservice teachers can read each other's reflective notes, discuss and provide feedback to one another under the guidance of a teacher-educator. They can be educated to become a self-reflective community of learners. Again, such learning can be scheduled to begin during the methods courses. Third, the teaching practicum can be divided into an observation *cum* deliberation phase that blends into a teaching *cum* deliberation phase. Fourth, during the observation phase experiences with different instructional milieu may be more beneficial for the development of a knowledge of practice. In a nutshell, we postulate that an extensive practicum that engages student teachers in reflection and deliberation scaffolded by support and guidance may better prepare beginning teachers for excellence in practice.

ACKNOWLEDGMENTS

This study was funded by a research grant from the Hamilton campus of Miami University. Any opinions, findings, and conclusions or recommendations expressed in this chapter are those of the authors and do not reflect the views of the university.

REFERENCES

Adler, S., & Goodman, J. (1986). Critical theory as a foundation of methods courses. *Journal of Teacher Education, 37*(4), 2-7.

Berliner, D. C. (1987). Ways of thinking about students and classrooms by more or less experienced teachers. In J. Calderhead (Ed.), *Exploring teachers' thinking*. London: Cassell.

Biott, G. (1983). The foundations of classroom action research in initial teacher training. *Journal of Education for Teaching, 9*, 152-160.

Brickhouse, N., & Bodner, G. M. (1992). The beginning science teacher: Classroom narratives of convictions and constraints. *Journal of Research in Science Teaching, 29*, 471-485.

Brown, A. L., & Palincsar, A. S. (1989) Guided, cooperative learning and individual knowledge acquisition. In L. B. Resnick, *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 393-451). Hillsdale, NJ: Lawrence Erlbaum Associates.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Carr, W., & Kemmis, S. (1986). *Becoming critical: Education, knowledge, and action research.* London: Falmer Press.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick, *Knowing, leaning, and instruction: Essays in honor of Robert Glaser* (pp. 453-493). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cooper, J., & Mueck, R. (1990). Student involvement in learning: Cooperative learning and college instruction. *Journal on Excellence in College Teaching, 1*, 68-76.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed.), (pp. 119-161). New York: Macmillan.

Goodman, J. (1986). University education courses and the professional preparation of teachers. *Teaching and Teacher Education, 12*(2), 102-109.

Gore, J. M. (1987). Reflecting on reflective teaching. *Journal of Teacher Education, 38*(2), 33-39.

Gore, J. M., & Zeichner, K. M. (1991). Action research and reflective teaching in preservice teacher education: A case study from the United States. *Teaching and Teacher Education, 7*(2), 119-136.

Guba, E., & Lincoln, Y. (1989). *Fourth generation evaluation*. Beverly Hills, CA: Sage.

Johnson, R. T., & Johnson, D. W. (1985). Student-student interaction: Ignored but powerful. *Journal of Teacher Education, 36*(4), 22-26.

Kottkamp, R. B. (1990). Means for facilitating reflection. *Education and Urban Society, 22*(2), 182-203.

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge: Cambridge University Press.

Lanzara, G. F. (1991). Shifting stories: Learning from a reflective experiment in a design process. In D. A. Schön (Ed.), *Reflective turn* (pp. 285-320). NY: Teachers College Press.

Lortie, D. C. (1975). *Schoolteacher: A sociological study*. Chicago: University of Chicago Press.

Martens, M. L. (1992). Inhibitors to implementing a problem-solving approach to teaching elementary science: Case study of a teacher in change. *School Science and Mathematics, 92*(3), 150-156.

McCarthy, C. (1986). Teacher training contradictions. *Education and Society, 4*(2), 3-15.

McCutcheon, G., & Jung, B. (1990). Alternative perspectives on action research. *Theory into practice, XXIX*(3), 144-157.

MacKinnon, A. M., & Erickson, G. L. (1988). Taking Schön's ideas to a science teaching practicum. In P. Grimmett, & Erickson, G. L. (Eds.), *Reflection in Teacher Education*. (pp. 67-90). NY: Teachers College Press.

Pratt, H. (1981). Science education in elementary school. In N.C. Harms, & R.E. Yager (Eds.), *What research says to the science teacher* (Vol. 3, pp. 73-94). Washington, DC: National Science Teachers Association.

Rogoff, B., & Lave, J. (Eds.) (1984). *Everyday cognition: Its development in social context*. Cambridge, MA: Harvard University Press.

Roychoudhury, A., & Heckman, D. (1992, March). An afterthought: Teachers' views about boys and girls. Paper presented at the annual conference for the National Association of Research in Science Teaching, Boston, MA.

Roychoudhury, A., & Roth, W. M. (in press). Student involvement in learning: Collaboration in science for preservice elementary teachers. *Journal of Science Teacher Education.*

Rudduck, J. (1985). Teacher research and research-based teacher education. *Journal of Education for Teaching, 11*, 281-289.

Russell, T., & Munby, H. (1991). Reframing: The role of experience in developing teachers' professional knowledge. In D. A. Schön (Ed.), The reflective turn: Case studies in and on educational practice. (pp. 164-187). NY: Teachers College Press.

Russell, T., Munby, H., Spafford, C., & Johnston, P. (1988). Learning the professional knowledge of teaching: Metaphors, puzzles, and the theory-practice relationship. In P. Grimmett, & Erickson, G. L. (Eds.), *Reflection in Teacher Education*. (pp. 67-90). NY: Teachers College Press.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Schön, D. A. (1987). *Educating the reflective practitioner*. San Francisco: Jossey-Bass.

Shulman, L. S. (1988). The dangers of dichotomous thinking in education. In P. Grimmett, & Erickson, G. L. (Eds.), *Reflection in Teacher Education*. (pp. 67-90). NY: Teachers College Press.

Slavin, R. E. (1991). Synthesis of research on cooperative learning. *Educational Leadership, 38*(8), 71-82.

Chapter 6

Multicultural Infusion: A Culturally Affirming Strategy for Science Teacher Preparation

Roberrta H. Barba
Rebecca S. Bowers

African American, Hispanic/Latino, Native American, and other culturally diverse individuals comprise approximately 18% of the American population; but only 2.2% of our technical work force (Hill, Pettus & Hedin, 1990). Despite the legal removal of social barriers to these students' full participation in technical careers, the numbers of culturally diverse students enrolled in mathematics, science, computer science, and engineering studies remains low (VanTassel-Baska, Patton & Prillaman, 1989).

Culturally diverse individuals have made significant career gains in many areas of business and industry. Nevertheless, as a result of inadequate science and mathematics academic preparation, many high-ability and high-potential culturally diverse students face not only educational barriers but also economic barriers in their training for highly technical jobs. The gap between low socio-economic status (SES) and higher SES levels is widening as the upward mobility rate of low SES individuals is less than 3% per generation at the current time (Burbridge, 1991; Schick & Schick, 1991).

Many culturally diverse students, especially those who speak a first language other than English, consistently perform lower on standard measures of academic achievement (e.g., SAT, GRE, MAT) than do their peers whose primary language is English (Schick & Schick, 1991). In addition, many suburban minority students achieve lower on tests of higher-order thinking skills than do their nonminority peers (Levine & Eubanks, 1990). Although high school drop-out rates at all socioeconomic levels are higher for culturally diverse students than for students of European descent, the high school graduation rate for African-American students has gradually improved since the passage of the 1965 Civil Rights Act. During the same time period, however, the high school graduation rate for Hispanic/Latino and certain Southeast-Asian students has actually declined (Schick & Schick, 1991).

University participation rates among culturally diverse and low-income students provide good indicators of progress in educational equity. Historically, most culturally diverse students enroll in two-year community colleges rather than at four-year degree granting institutions (Carter & Wilson, 1991). In 1989, 23.5% of African-American high school graduates were enrolled in colleges and universities, compared with 16.1% of Hispanic/Latinos and 31.8% of whites (Digest of Educational Statistics, 1990). This trend toward community college enrollment by culturally diverse learners results in a situation in which the earning capacity of individuals is limited by their education.

Recent literature has attributed the under-representation of minority students in science fields to a variety of factors, such as: (a) lack of student interest in science (Berryman, 1983; Clark, 1986; Entwistle & Duckworth, 1977), (b) science anxiety (Clawson, Firment & Trower, 1981; Czerniak & Chiarelott, 1985), (c) personality factors (Clark, 1986; Harlen, 1985), (d) white male dominated images of science (AAUW, 1992; Hill, Pettus & Heddin, 1990; Kahle, 1985), (e) lack of minority role models in science and related technology careers (Sadker & Sadker, 1979; Powell, 1990), (f) socio-economic barriers (Patchen, 1982), (g) improper counseling regarding academic track coursework at the high school level (Marrett, 1981), (h) teacher attitudes and expectations (Karlin, Coffman & Walter, 1969), and (i) lack of proper academic preparation (Harlen, 1985; Oakes, 1990). With these and possibly other factors contributing to the low participation by culturally diverse students in science, mathematics, and related scholarly pursuits, the end result is that a significant portion of America's children are not being prepared to participate in science-related careers in adult life.

Today in New Mexico and California, culturally diverse school-aged populations outnumber students of European descent (Elementary Grades Task Force of the California Department of Education, 1992). Within the next decade, the other forty-eight states will experience this same demographic change (Carter & Wilson, 1991). We are rapidly becoming a nation of ethnic and racial "unmeltables" (Novak, 1971), a nation in which culturally diverse children are disenfranchised in science and related careers.

In view of such cultural pluralism, the National Science Teachers Association Board of Directors asserted in its Multicultural Science Education Position Statement that "culturally diverse children must have access to quality science education experiences that enhance success and provide the knowledge and opportunities required for them to become successful participants in our democratic society" (NSTA, 1991). In addition, the NSTA Board of Directors wrote that "curricular contents and instructional strategies selected for use with culturally diverse children must reflect, as well as incorporate this diversity" (NSTA, 1991). To meet these NSTA guidelines for multicultural education, the NSTA Board wrote "science teachers must be knowledgeable about children's learning styles and instructional preferences, which may be culturally related" (NSTA, 1991). Therefore, science teacher educators must prepare and mentor science teachers so that they are able to meet the needs of our nation's culturally diverse student population.

ETHNIC STUDIES APPROACH

Traditionally, college and university teacher educators, including science teacher preparation faculty, have attempted to address the needs of culturally diverse learners by an ethnic studies approach (Givens, 1982). Typically, ethnic studies courses have included content dealing with topics such as race relations or racial/ethnic sensitivity training for both preservice and inservice teachers. Garcia (1980) wrote that the race relations or sensitivity training approach "is based on the operational assumption that increased knowledge about an ethnic group can foster positive attitudes toward that ethnic group" (p. 116). Moreover, only teachers who planned to work in inner-city school systems or in other areas with large numbers of bilingual/bicultural students received such training.

When cultural awareness, race relations, or sensitivity training is incorporated into preservice teacher preparation programs, an ethnic studies course typically includes information about the heritage, language, foods, holidays, customs, beliefs, and attitudes of various racial and ethnic groups (Garcia, 1980). Advocates of the ethnic studies approach to teacher education maintain that teachers' awareness of the beliefs, attitudes, and values of other ethnic groups can eliminate ethnic bias, stereotyping behaviors, and racial discrimination in classroom interactions and dynamics (Garcia, 1980, p. 118). Thus, the quality of instruction received by culturally diverse learners will improve.

While thousands of position papers have been written about the need for ethnic studies programs, about curricula to support such programs, and about inservice preparation for teachers in culturally diverse schools, relatively few controlled studies have been conducted to measure the educational effectiveness of these programs. Studies by Giles (1977), Jeffcoate (1979), and Rex and Tomlinson (1979) indicate that ethnic studies courses can change teachers' attitudes toward culturally diverse learners. To investigate the effects of teachers' attitude(s) toward culturally diverse learners in British schools, Green (1982) conducted 3,000 classroom observational periods, which involved 70 teachers of European descent and 1,814 students (940 of European descent, 449 Asian and 425 West Indian). Based on his analysis of observational data, Green reached the following conclusions:

- Teachers of European descent with negative attitudes towards West Indian children give significantly less time to accepting the feelings of these children;
- Biased teachers give minimal praise to culturally diverse children;
- Biased teacher rely on direct teaching methods as appropriate instructional strategies for culturally diverse learners;
- Teachers of European descent with a negative attitude toward West

Indian children give significantly more authoritative directions to these children; and

- Highly intolerant teachers give culturally diverse learners significantly fewer opportunities to contribute to classroom discussion.

Although research indicates that the ethnic studies approach to teacher education does facilitate improved teachers' attitudes toward culturally diverse learners, there is no evidence that such an approach to teacher preparation results in improved instructional quality for or learning by these students. Indeed, the opposite may be the case. Gay (1983) pointed out that "educators have long operated on the belief that a teacher who could teach any student could teach all students" (p. 79). Gay further suggests that most teachers are "ethnically illiterate" and that the instructional strategies they use do not address the characteristics and needs of culturally diverse learners.

In addition to the studies conducted by teacher educators, sociologist James Banks (1981) argues that an ethnic studies approach to preservice teacher education is not sufficient to bring about effective educational reform or equity. Like teacher educators, Banks concludes that, while an ethnic studies approach does address teacher attitudes toward culturally diverse students, this approach does not confront multicultural instructional considerations, nor does it deal with preservice teachers' content area pedagogical knowledge or the need for field experience in a community similar to the one in which they will teach.

MULTICULTURAL EDUCATION AND DIVERSITY

Gilbert and Gay (1985) contend that "the means appropriate for teaching poor, urban Black students differ from those appropriate for teaching other students because teaching and learning are sociocultural processes that take place within given social systems" (p. 134). Without full consideration to the social and cultural aspects of learning, science educators teach preservice teachers such ideas as "meaning is constructed by each individual child," "knowledge is constructed within a socio-cultural context," and "learning occurs as the child struggles to make sense of their world."

Tobin, Tippins, and Hook (1992) point out that "an individual is born into a social and cultural environment where all of the objects and events which are encountered have particular meanings within the social context" (p. 2). Other researchers confirm that mastery of content area knowledge encompasses an interplay between culture, including language, and concept formation (Healy, 1990; Jegede & Okebukola, 1992; Koopmans, 1987; Olson, 1986; Olson & Torrance, 1987; Pitman, 1989; Sless, 1984; Valle, 1978; Verhoeven, 1987). Historically, many culturally diverse children have encountered school-taught science in a culturally unfamiliar manner as well as in an unfamiliar language. As a result, these students never acquire the desired level of language proficiency, nor do they "understand" the science concepts taught in the classroom (Ornstein-

Galicia & Penfield, 1981). Ornstein-Galicia and Penfield and other researchers, therefore, point out that the interplay between the child's culture and the child's way of "wrestling with knowledge" or constructing new knowledge is an issue which has been excluded from most science teacher preparation programs.

In addition to their means of constructing new knowledge, many culturally diverse learners find that their ways of thinking, knowing, and socially interacting are unacceptable in the science classroom. For example, some white teachers consider young African-American students' "stage setting behaviors" (e.g., walking in a swaggering motion to the pencil sharpener or borrowing a sheet of notebook paper from a neighbor before beginning academic work) to be rude, inappropriate, and threatening (Longstreet, 1978). Some teachers view the "wearing of colors" (e.g., wearing Raiders, Sox, and Kings baseball style caps, using red bandannas as "rags" or hats, "bagging" chino trousers and wearing black clothing—especially Starter brand jackets) as, at least, socially unacceptable behaviors, or, at worse, gang-related activities. But such "wearing of colors" are routine in the "hoods" and *barrios* of west coast inner-city communities. Thus, the student's dilemma is that social interaction rules and learning patterns acquired at home and in the child's community become an impediment as the student struggles to make sense of school learning and school ways of doing things.

Other studies, which include student populations of Asian and Native American descent, concur with conclusions reached by Longstreet (1978), and Ornstein-Galicia and Penfield (1981). For example, in a study of the Hmong students' learning patterns, Hvitfeldt (1986) found that cultural variables influenced verbal interaction patterns in the classroom, student's preferred learning modes, and students' concept acquisition. Studies with Hawaiian-American (Au, 1980; Au & Jordan, 1977; Spring, 1950; Weisner, Gallimore & Jordan, 1988), Asian-American (Cheng, 1992), African-American (Stewart & Benson, 1988) and Native-American (Harris, 1985; Rhodes, 1988) children indicate that the students' cultures influence the ways in which they interact with teachers and the way(s) they construct knowledge in the classroom. Moreover, as children grow into adults, their ways of interacting and constructing knowledge become ingrained into the fabric of their personalities.

Research cited in this section advances the mandate that educators who identify appropriate instructional strategies for culturally diverse learners must recognize that diversity represents many different cultures and belief systems: Multicultural education in not monolithic. Effective and appropriate instructional strategy identification must be integrated with consideration of country-of-origin, level of assimilation with the mainstream culture, degree of acculturation, socioeconomic status, and individual differences, including learning style preferences. Mexican-American, Puerto Rican-American, Central-American, South-American, and Cuban-American students may, for example, share a common language, but beliefs, values, attitudes and cultural histories differ from one individual to another. Pang (1988) cautions educators to avoid attributing the same characteristics to all members of a particular ethnic group, thus stereotyping all individuals in that ethnic group.

Needs of Culturally Diverse Learners

While most culturally and linguistically unassimilated Hispanic/ Latino children prefer a highly visualized presentation of declarative information (Flora, 1980; Hill & Browner, 1982; Horn, 1983), it must be kept in mind that not all Hispanic/Latino students share a preference for this type of textual materials. Children's needs and interests must be accommodated on a case-by-case basis. At the same time, however, because the majority of students from this cultural background do prefer highly visualized materials, attention must be given to the research on visualization studies (Costantino, Malgady & Rogler, 1988; Fradd & Hallman, 1983; Ortiz & Maldonado-Colon, 1986). These studies suggest that students' preferences regarding mode of information presentation (i.e., whether information is conveyed in an oral or written format) is a culturally dependent variable. Dwyer (1978), Pitman (1989), Reed (1991), and Sless (1984) add that some culturally diverse learners appear to prefer a highly visual or pictorial presentation, rather than an oral or printed version of the same information. Research reveals that unassimilated Hispanic/Latino and certain Southeast-Asian learners acquire more verbal information from textual materials printed in a *fotonovela* or photonovel (a highly visual story book format) than from traditional textbooks (Comes-Diaz, 1984; Costantino, Malgady & Rogler, 1988; Flora, 1980; Hill & Browner, 1982; Horn, 1983; le Boterf, 1984). Flora (1980) additionally points out that unassimilated Hispanic/Latino and certain Southeast-Asian students prefer the fotonovel (which is commonly used in third world literacy campaigns) over traditional Eurocentric textbooks.

In addition to studies concerning reading materials, research focused on content area concept acquisition indicates that instruction in the "home language" for purposes of cued recall proportionally benefits those students who are not fully assimilated linguistically into mainstream American culture (Cortes, 1986; Cummins, 1979; Ehindero, 1980; Olson, 1986; Ortiz & Maldonado-Colon, 1986; Watts, 1986). Advantages of classroom instruction in students' native language are that it (a) builds students' self-esteem (Cohen, DeAvila, Navarette & Lotan, 1988; Cohen & Lotan, 1990; Ortiz & Maldonado-Colon, 1986), (b) improves students' attitudes toward schooling (Cummins, 1979; Ehindero, 1980; Pitman, 1989), (c) facilitates content area acquisition of declarative knowledge, (Cummins, 1979; Flora, 1980; Horn, 1983; Pitman, 1989) and (d) aids in mainstream English language development (Flora, 1980; Horn, 1983; Pitman, 1989). Wheatley (1991) points out that new knowledge is integrated with existing knowledge only when a student restructures and elaborates on existing knowledge (which the student may have constructed in his or her native language). Teachers in traditional science classrooms rarely encourage students to use their "home language." Culturally affirming classroom teachers would advocate the use of "home language" in small-group settings for cued recall and would urge students to bring their "home learning" to class and combine that with their "school learning."

Student concept acquisition also is enhanced using peer tutoring in a learner's home language or native language, especially when new concepts and/or vocabulary are introduced in a class (Cohen & Lotan, 1990; Cohen, Lotan & Catanzarite, 1986). Since negotiating meaning and building a personal rendition of knowledge through social interactions are foundational in the learning process, peer tutoring in a student's "home language" appears to be an effective means for bridging linguistic barriers of bilingual/bicultural students (Knight & Kagan, 1977; Ortiz, 1988) and for conferring status to unassimilated students (Cohen & Lotan, 1990; Cohen, Intili & Robbins, 1979). Other research indicates that most culturally diverse learners profit from cooperative group work and peer tutoring in terms of cognitive growth, attitude change, and self-esteem (Cohen, Lotan & Catanzarite, 1986; Cohen, Intili & Robbins, 1979; Cohan, Lotan & Leecher, 1989; Ortiz, 1988; Watson, 1991). The use of cooperative learning groups is especially advantageous to culturally diverse students in that their attitudes toward science and school, in general, improve (Cohen & Lotan, 1990; Cohen, Lotan & Catanzarite, 1986; Pitman, 1989; Ramirez & Castaneda, 1974; Rodriguez & Bethel, 1983; Watson, 1991). It is disconcerting to note that, while research has shown that cooperative learning is highly effective in meeting the educational needs of culturally diverse learners, studies have shown that cooperative learning is rarely used in practice in science classrooms (Raizen, 1991).

The inadequate representation of culturally familiar role models in science classrooms and science textual materials characterizes another area of concern for advocates of culturally affirming classrooms. It has been well documented that the presence of culturally familiar role models or significant others (such as the classroom teacher or community resource persons), both in person and in printed materials or textbooks, positively impacts the cognitive learning of all students (Alic, 1986; Bandura, 1962; Cicourel, 1974; Kahle, 1985; Pearson & Bechtel, 1989; Shade, 1982; Tanner & Lindgren, 1971; Van Sertima, 1986). It has been further demonstrated that the presence of culturally familiar role models in textual materials significantly increases students' self-esteem, concept acquisition, and motivation to pursue science careers (Cicourel, 1974; Healy, 1990; Pitman, 1989; Tanner & Lindgren, 1971).

Like role models, culturally familiar elaborations (that utilize objects, environments or contexts, examples, and analogies) function as powerful variables in concept acquisition by culturally diverse students (Kessler & Quinn, 1980; Rodriguez & Bethel, 1983; Watts, 1986; Williams, Fast, Berestiansky, Turner & Debreuil, 1979). Research has shown that culturally familiar contexts are concurrent with a significant increase in students' acquisition of declarative knowledge (Halpern, Hansen & Riefer, 1990; Kessler & Quinn, 1980; Rodriguez & Bethel, 1983). Other research (Cummins, 1979; Ehindero, 1980; Olson, 1986; Ortiz & Maldonado-Colon, 1986; Watts, 1986) has shown that culturally familiar examples proportionally benefit those students who are not yet culturally or linguistically assimilated into mainstream American culture. Additionally, increased student self-esteem has been found to result from the utilization of culturally familiar objects, contexts, examples, and analogies (Cohen & Lotan, 1990; Cohen, Lotan & Catanzarite, 1986; Cohen, Lotan & Leechor, 1989), as has an increased rate of student mastery of content area concepts (Ornstein-Galicia, 1981; Rodriguez & Bethel, 1983).

Other culturally derived instructional strategies, such as the talk story (Au & Jordan, 1977), holistic learning (Rhodes, 1988), students' geocentric perspectives (Van Otten & Tsutsui, 1983), bidialectic expression (Hochel, 1983; Cronnel, 1981; Levine, 1976), and stage setting behaviors (Longstreet, 1978; Shade, 1979) have been identified as being salient variables in culturally diverse learners' educational experiences. Teachers whose goal is to infuse a multicultural approach into their science instruction would benefit from additional study of these instructional strategies.

It is well documented by research that multiple means of knowledge representation and learning strategies benefit all learners; yet, many science teachers rarely hold "hands-on" manipulative activities in the same regard that they view textbook-based activities (Raizen, 1991). Interaction with laboratory equipment and/or manipulative materials increases the learning of conceptual or declarative knowledge among students (Cohen, Lotan & Catanzarite, 1986; Ramirez & Messick, 1976). Recent studies provide evidence that student interaction with manipulative materials positively impacts students' attitudes towards science (Cohen & Lotan, 1990; DeAvila, Duncan, Navarrete, 1987). Other research indicates that students who use laboratory and/or manipulative materials experience significant increases in the speed with which they master concepts, along with enhanced competence in problem-solving skills (Ornstein-Galicia, 1981; Comes-Diaz, 1984; Kessler & Quinn, 1980; Brown, Fournier & Moyer, 1977). Yet, science classroom instruction typically offers few experiences using a "hands-on" approach or other effective multiple representations of instructional practices. The result is a less than adequate science learning experience for all students and a culturally nonaffirming classroom environment for culturally diverse students.

Needs of Preservice Science Teachers

In summarizing research on teacher education efforts in California (the state with the largest population of culturally diverse learners in the nation), LoPresti (1985) points out that five components are common to preservice teacher education programs that successfully address the needs of teachers in multicultural classrooms. The five components of LoPresti's teacher preparation model include: (a) a broad general education, (b) subject matter competency, (c) an awareness of the needs of culturally diverse children, (d) content area pedagogical knowledge, and (e) field experience in working with culturally diverse learners. Most colleges and universities in this nation adequately address the broad general education and content area knowledge components (i.e., science) of LoPresti's model. However, most colleges and universities do not provide the multicultural awareness, content area pedagogical knowledge, and field experience components necessary to prepare preservice science teachers for success in multicultural science classrooms and the ones that LoPresti identified as being essential in preparing teachers to work in culturally diverse settings.

Multicultural Awareness

While traditional ethnic studies courses for teachers focus on holidays, customs, and beliefs of culturally diverse learners; courses with a multicultural education focus assist teachers to change social practices so that their classrooms are conducive to the needs of all learners in a democratic society (Suzuki, 1984). Sleeter and Grant (1987) write that multicultural education is a multidisciplinary educational approach that seeks to assist students in gaining a better understanding of the causes of oppression and inequality in American society and a knowledge of ways in which these social problems might be eliminated.

In a controlled study comparing a multicultural education approach with a traditional ethnic studies approach to developing cultural awareness, Dunbar (1980) found that a multicultural education approach improves a participants' ability to clarify their own attitudes and perceptions toward other ethnic groups (other than the one to which they belong). While investigating ways of restructuring preservice teacher preparation programs, Bennett (1979) found that a multicultural education approach (a) alters preservice teachers' attitudes towards other racial and cultural groups, (b) provides preservice teachers with an increased sense of self-efficacy about their abilities to work with inner-city children, (c) provides participants with an increased knowledge base regarding racial and cultural groups in American society, and (d) results in an increased awareness of the preservice teachers' own ethnic heritage. The incorporation of a multicultural education courses into preservice teacher education programs has been shown to be an effective means for preparing preservice teachers to work in multicultural classrooms and an effective means with which to address the educational, social, linguistic, and psychological needs of culturally diverse learners (Gay, 1983; Grant, 1981; Payne, 1980; Sims, 1983).

Field Experiences

Mahan and Lacefield (1982) investigated field experience in working with culturally diverse learners. In a controlled study, these researchers compared 655 preservice teachers who completed a field experience in classrooms where the students were primarily of European descent with 2,178 preservice teachers who taught in multicultural classrooms. They found that a field experience in a culturally diverse classroom (a) increased the likelihood of employment of preservice teachers, (b) increased preservice teachers' efficacy in working with culturally diverse students, and (c) facilitate the acceptance of Anglo teachers in culturally diverse neighborhoods.

In their study of the effectiveness of a field experiences in culturally diverse schools, Cooper and Morey (1989) found that such a field experience, under the supervision of a master teacher and resource teacher, increased the retention rate of preservice teachers in culturally diverse school districts. Likewise, studies conducted at Ball State University (Payne, 1980), Texas A&M University (Mangan, 1991), Indiana University Northwest (Woerner, 1992), Indiana University-Bloomington (Mahan & Lacefield, 1982), and Stanford University (Cohen & Lotan, 1990) indicate that supervised field experiences in culturally diverse neighborhoods increase the chances that teachers will experience success in teaching culturally diverse learners.

Content Area Pedagogical Knowledge

In concert with LoPresti's position that content area pedagogical knowledge should be structured to address the educational needs of culturally diverse learners, Gay (1983) wrote that "preservice professional preparations should include knowledge about ethnic and cultural diversity, the creation and selection of instructional materials that reflect ethnic and cultural pluralism, and the translation of that knowledge into multiculturalized lesson plans and strategies for instruction" (p. 82). While many writers have echoed Gay's viewpoints, few have provided specific frameworks or instructional strategies for modifying existing "methods" courses so that they address the needs of preservice teachers preparing to work in multicultural classrooms.

Cohen and her associates at the Center for Complex Instruction at Stanford University provide some of the first empirical evidence that teacher education courses can be modified to accommodate the needs of science teachers in multicultural classrooms, along with the education needs (e.g., linguistic social, emotional, and science concept knowledge) of culturally diverse learners in those classrooms. (Readers who want to read the studies conducted by Cohen and her associates are referred to the following sources: Cohen, 1991; Cohen, DeAvila, Navarette & Lotan, 1988; Cohen, Intili & Robbins, 1979; Cohen & Lotan, 1990; Cohen & Lotan, 1991; Cohen, Lotan & Catanzarite, 1986; Cohen, Lotan & Leechor, 1989; Lotan, Swanson & LeTendre, 1991).

Pilot studies (Philipp, Armstrong & Bezuk, 1992; Philipp, Flores & Sowder, 1992) conducted at San Diego State University into the effectiveness of a "multicultural infusion" approach to preservice teacher preparation indicate that such an approach is not only highly feasible, but also is highly effective in producing inservice and preservice teachers who are capable of meeting the educational needs of culturally diverse students. Philipp, Armstrong, and Bezuk (1992) point out that preservice teachers working in multicultural classrooms can be coached and mentored to incorporate knowledge gained in methods courses into daily classroom practice. Preservice teachers coached to consider the needs of culturally diverse learners consider "individual students when making curricular decisions" (p. 29). From a year long, in-depth study of a preservice teacher's student teaching and coursework experiences in a teacher credentialing program, these authors learned that this preservice teacher readily incorporated pedagogical content knowledge into her teaching practices. They point out that pedagogical content knowledge focusing on research-based instructional strategies appropriate for culturally diverse students is readily accepted by preservice teachers because, "unlike inservice teachers, they don't have anything to overcome" (p. 29). From a study of inservice teachers in multicultural classrooms this same research group (Philipp, Flores, Sowder & Schappelle, 1992) learned that incorporating a knowledge of individual learners and instructional strategies appropriate for the learners into teacher inservice programs produces reflective practitioners, i.e., teachers who understand the milieu of the school and the community and how these are interrelated (p. 35).

MULTICULTURAL INFUSION IN SCIENCE TEACHER EDUCATION

In the past, many teacher educators, including science educators, have tended to view the needs of culturally diverse learners as being a problem of those involved in bilingual education, or inner city schools, rather than as a mainstream science education concern (Gilbert & Gay, 1985). By contrast, multicultural infusion is the conscious and consistent inclusion of a consideration of the needs of culturally diverse learners into all areas of science teacher preparation. We maintain that the research discussed previously in this chapter indicates that multicultural infusion is the most appropriate means to prepare preservice science teachers to work in multicultural classrooms. In this section of the chapter, recommendations for infusing into teacher preparation courses instructional strategies, values, attitudes, and methods, which follow from the research reviewed above, are made in five areas: (a) changes in the way that we view learners and teachers; (b) inclusion of instructional strategies appropriate for culturally diverse learners; (c) modifying science content so that it is relevant to the lives of diverse learners; (d) integration of language acquisition strategies into existing science methods courses; and (e) attention to the social and cultural needs of culturally diverse learners.

Teaching and Learning

Historically, science, and therefore science teaching and learning, have been predicated on foundations of objectivism. This belief system includes the notion that the teacher is the authority figure, the one who dispenses knowledge. Models of teaching and learning derived from this philosophical orientation in many cases are not appropriate for use with culturally diverse learners. Indeed, research previously discussed in this chapter indicates that highly authoritative, teacher-directed learning models are probably inappropriate for most culturally diverse learners.

McDowell (1990) pointed out that "teachers' ability to foster children's understanding in science is partially dependent on their understanding of the mental models from which children operate" (p. 275). From a constructivist viewpoint, conceptual knowledge of science is constructed gradually over time by learners within a social context, through a series of interactions with content. The result is the integration of new information with old information and an awareness on the part of the learner of what is being learned (Roehler & Duffy, 1989, p. 116). In contrast with proponents of objectivism, constructivists hold that knowledge is constructed, not transmitted. Moreover, "learning occurs within a social context as students share their ideas with peers, both in small groups and within the total society of the classroom" (Wheatley, 1991, p. 12). From a multicultural infusion perspective, then, schools rather than students are "at risk," especially when they do not capitalize upon the richness of experience that culturally diverse learners bring to classroom social interactions.

Although many science teacher educators have moved to and now advocate a constructivist viewpoint, these same educators may not have consciously made a connection between the constructivist worldview and the needs of culturally diverse learners. Consideration of the socio-cultural context of learning, the learner's personal culture within the "culture of the classroom," needs to be included within the constructivist perspectives being brought to science teacher education. Given the demographic changes that are occurring, it is recommended that constructivist theories of learning be used as a psychological and socio-cultural foundation in science teacher education.

Instructional Strategies

Because multicultural infusion mandates that consideration of culturally diverse learners' needs permeate all science education instructional activities, science teacher educators should help preservice teachers' make connections between the qualities of instructional strategies and the needs of culturally diverse learners. Instructional strategies appropriate for use with culturally diverse learners are those that include: tasks (i.e., questions or problems that have not been previously encountered by the learner), groups, and sharing (Wheatley, 1991). Specifically, inquiry-based instructional strategies that incorporate group or cooperative learning activities and provide students multiple means of representing their knowledge are effective instructional strategies for culturally diverse learners. Research (Cobern, 1991; Driver & Bell, 1986; Driver & Oldham, 1986, Roth, 1990 & Wheatley, 1991) suggests that learning models that use thematic problem-solving approaches to learning are highly effective for culturally diverse learners because they (a) provide multiple means of data representation, (b) allow for peer tutoring, (c) provide for the use of home language in small groups, (d) allow students to bring culturally familiar examples and elaborations into the classroom, (e) permit students to interact with manipulative materials, (f) encourage students to work cooperatively in constructing new knowledge, and (g) "fit" with what is known of the teaching/learning process from research in cognitive psychology.

The learning cycle is one instructional strategy that appears to be especially appropriate for culturally diverse learners because it promotes problem solving or inquiry learning, and can include cooperative group work, peer tutoring, and the sharing of findings with others in the class (Bowers, 1991). In addition, the learning cycle provides a setting for learners to discuss science concepts with each other in their "home language" or native language. The use of manipulative materials as part of most learning cycle activities accommodates culturally diverse students' needs for multiple modes of knowledge representation.

Closer examination of the learning cycle reveals additional benefits for culturally diverse students. Learning cycle methodology encourages students to draw examples of scientific concepts from the context of their own interests and lives. This inquiry-based approach focuses on open-ended questions, which allow all students to bring their "home learning" into the classroom and to generate multiple solution paths. Some of the multiple solutions may be derived from the students' previous experience in their home communities. In addition, Vygotsky (1962) pointed out that children can, in groups, perform that which they cannot do by themselves. Finally, the learning cycle can accommodate multiple means for students to present their new learning to others in such ways as oral reporting, concept mapping or word webbing, journal entries, portfolios, drawings, diagrams, graphs, poems, rap songs, and other methods that might be suggested by the student or encouraged by the teacher.

It should be noted that whenever multiple means of presenting knowledge and of sharing learning experiences are incorporated into instructional activities, the linguistic needs of culturally diverse learners are more readily addressed. Instructional strategies that allow the student to build linguistic and conceptual bridges between "home learning" and "school learning" are crucial in the multicultural science classroom. Aside from the learning cycle, other instructional strategies that allow "bridge building" behaviors to occur in the classroom include (a) interactive reading activities conducted in small heterogeneous groups (e.g., ITM, Inductive Teaching Methods; QUEST, QUEstions that Stimulate Thinking; TRICA, Teaching Reading In the Content Area techniques), (b) hands-on, inquiry based activities, (c) large group mediated conversations, (d) visually enhanced expository teaching techniques, (e) scaffolding techniques (such as that incorporated in *The Popcorn Book*), and (f) small-group negotiated conversations. The learning cycle and these related instructional strategies that are appropriate for use with culturally diverse learners are recommended to be emphasized in science teacher education.

Relevant Curriculum

The California State Board of Education (1990) wrote, "the standards of success must be equivalent for all students so that a common metric is understood and appreciated by all students" (p. 169). Application of this state board of education guideline and other comparable guidelines directs that multicultural infusion in science does not mean "lowering the standards." Rather, the guiding principle and end result would be to make the standards accessible to all students. A cursory examination of science textbooks, videos, movies, filmstrips, and computer tutorials reveals that they lack culturally diverse representations of people, and examples of objects and experiences familiar to a culturally diverse population. For example, textbooks and resource materials used in science classrooms frequently incorporate analogies, metaphors, and elaborations based on the rural American farm experience. Such materials may include stories of chickens hatching eggs, of cows giving birth, or of corn growing in the fields. These particular elaborations may be commonly known to mainstream rural and suburban youth, but they are unfamiliar to many inner-city students. Likewise, the mention of a fuse box or a circuit breaker in a physics textbook is a referent unknown to children living in high-rise apartment buildings. References to oaks, poison ivy, and Staghorn sumac, commonly found in deciduous hardwood forests, may be appropriate for students living in the northeast quadrant of the United States, but these examples hold little meaning for Mexican-American students in the southwest quadrant who are accustomed to seeing gramma grass, prickly pear cacti, and Joshua trees.

Research has already been noted and discussed in this chapter which provides evidence that incorporating culturally familiar elaborations and content enhances culturally diverse students' science concept acquisition (Cohen, DeAvila, Navarette & Lotan, 1988; Cohen, Intili & Robbins, 1979; Cohen & Lotan, 1991; Lotan, Swanson & LeTendre, 1991). It is recommended that preservice science teachers be coached in personalizing the curriculum by including examples from students' own lives as a part of everyday classroom instruction. Additionally, preservice science teachers should be encouraged to include culturally diverse role models (e.g., culturally diverse men and women of science) in science instruction.

Language Acquisition Skills

Culturally diverse learners frequently speak a "home language" or native language different from mainstream America. Recent studies (Mason & Barba, 1992; Barba & Mason, in press) indicate that Limited English Proficient (LEP) students are frequently mainstreamed into regular science classrooms without proper linguistic support services. In addition, regular science classroom teachers are sometimes expected to teach science to large numbers of LEP students without a knowledge of language acquisition skills. As a result, teachers feel frustrated and students do not master science concepts or acquire proficiency in the use of the English language.

Monolingual English speaking teachers may address the needs of LEP students through the use of sound teaching practices, including "(a) simplifying the input, (b) providing context clues, (c) drawing on students prior background, (d) working to ensure understanding, (e) making sure that instruction is content-driven, (f) ensuring that instruction is student centered, and (g) using science textbooks effectively" (California Department of Education, 1990, pp. 170-171).

In addition to instruction on such teaching practices, it is recommended from the research (Cummins & Swain, 1986; San Diego City Schools, 1982) that language acquisition skills be infused into regular science teacher education programs in order to help prepare preservice science teachers to address the linguistic needs of bilingual students.

The daily use of language acquisition strategies in the classroom should lead science teachers to "make attempts to restate, redefine, provide culturally familiar examples, and draw on students' prior backgrounds when teaching science concepts" (California Department of Education, 1990, p. 170). Students who are not fully assimilated in the use of the English language rely on multiple means of knowledge representation (i.e., *realia*, oral words, written words, pictures, and icons) when attempting to construct a personal rendition of knowledge. Culturally familiar examples, analogies, and metaphors benefit LEP students. Preservice teachers should be mentored in the use of questioning skills in their science methods courses, questions that provide insights into the way(s) that children have constructed knowledge. They need to be skilled in the use of peer tutoring in the child's native language. Finally, preservice teachers should be able to use interactive, cooperative reading strategies such as the three-tiered study guide technique advocated by Herber (1978), when textbooks are used as an instructional medium. A study of these strategies and their primacy as tools for instructing culturally diverse students should be deliberately infused into preservice science teacher education.

Social and Cultural Awareness

King (1991) asserts that "prospective teachers need both an intellectual understanding of schooling and inequity as well as self-reflection or transformative emotional growth experiences" (p. 134). Earlier in this chapter it was pointed out that stereotyping culturally diverse children is a dangerous and insensitive practice. Therefore, all preservice science teachers need to develop an awareness and a sensitivity to the cultural, linguistic, and social variables in the lives of their students. We would argue that a knowledge of students and the communities in which they were reared are "basic skills" for all science teachers, especially for teachers in the multicultural classroom. A poignant example is that science teachers who instruct Vietnamese students in southern California need to have a very different classroom environment and experience than do their peers who teach bidialectic students in inner-city schools in the eastern United States. The language, culture, social values, and ethnic histories of students should influence the way(s) that information is presented to students, the examples that teachers use, and the instructional strategies that teachers select as being appropriate.

In preparing preservice science teachers for positions in multicultural classrooms, science educators should infuse an awareness of cultural diversity and the needs of culturally diverse learners in all areas of instruction. Again, it should be noted that multicultural infusion in science teacher preparation is differentiated from the "traditional" ethnic studies approach in that the goal of multicultural infusion is to develop an awareness of the educational needs of minority students in every science teacher and to translate that awareness into appropriate instruction for all children. Multicultural infusion produces "ethnically literate" science teachers who are capable of providing culturally affirming science instruction.

CONCLUSION

Consideration of the socio-cultural context of learning includes an awareness of the educational needs of culturally diverse learners. Multicultural infusion offers the opportunity for science teacher educators to prepare a new generation of science teachers who are capable of meeting the needs of culturally diverse learners. Research shows that effective preservice science teacher education programs need to include: a broad educational background, depth and breadth in science, field experiences in culturally diverse neighborhoods, multicultural studies, and relevant science education courses that provide content area pedagogical knowledge for future teachers in multicultural classrooms.

Existing science methods courses, and indeed all education courses, ought to be modified to address the needs of future teachers in multicultural classrooms by (a) the use of a constructivist approach to teaching and learning, (b) the incorporation of instructional strategies appropriate for culturally diverse learners, (c) the inclusion of relevant course content, (d) the introduction of language acquisition skills as part of teacher preparation, and (e) a focus on the social and cultural characteristics of diverse learners. Multicultural infusion produces culturally and ethnically literate science teachers who are able to meet the needs of culturally diverse learners.

REFERENCES

Alic, M. (1986). *Hypatia's heritage: A history of women in science from antiquity to the nineteenth century.* London: Women's Press.

American Association of University Women (1992). *The AAUW report: How schools shortchange girls.* Washington, DC: American Association of University Women Educational Foundation.

Au, K. H. (1980). Participation structures in a reading lesson with Hawaiian children: Analysis of a culturally appropriate instructional event. *Anthropology and Education Quarterly, 11*(2), 91-115.

Au, K. H., & Jordan, C. (1977). *A Multidisciplinary Approach to Research in Education: The Kamehameha Early Education Program.* Paper presented to the American Anthropological Association, Houston, TX.

Bandura, A. (1962). Social learning through imitation. In N.R. Jones (Ed.), *Nebraska symposium on motivation.* Lincoln, NB: University of Nebraska Press.

Banks, J. A. (1981). *Multiethnic Education: Theory and Practice.* Boston: Allyn and Bacon.

Barba, R. H., & Mason, C. L. (in press). The bilingual/bicultural science classroom: A baseline study. *Science Education.*

Bennett, C. T. (1979). The preparation of pre-service secondary social studies teachers in multiethnic education. *High School Journal, 62*(5), 232-237.

Berryman, S. (1983). *Who will do science*? New York: Rockefeller Foundation.

Bowers, R. S. (1991). Instructional models for effective middle schools science teaching. *Middle School Journal, 22*(4), 4-9.

Burbridge, L. C. (1991). *The interaction of race, gender and socioeconomic status in education outcomes.* Wellesley, MA: Center for Research on Women.

California State Board of Education (1990). *Science Framework for California Public Schools Kindergarten Through Grade Twelve.* Sacramento, CA: California Department of Education.

Carter, D. J., & Wilson, R. (1991). *Tenth annual status report: Minorities in higher education.* Washington, DC: American Council on Education, Office of Minorities in Higher Education.

Cheng, L. R. L. (1992, May). *Language Difference vs. Language Disorders: An ESL/EFL Perspective.* Paper presented at the jointly sponsored ESL Symposium (San Diego State University & National Kaohsiung Normal University, R.O.C.). San Diego, CA.

Cicourel, A. V. (1974). *Cognitive Sociology.* New York: Free Press.

Clark, M. (1986). Predictors of scientific majors for black and white college students. *Adolescence, 21,* 205-213.

Clawson, T., Firment, C., & Trower, T. (1981). Test anxiety: Another origin for racial bias in standardized testing. *Measurement and Evaluation in Guidance, 13,* 210-215.

Cobern, W. W. (1991, April). *Contextual constructivism: The impact of culture on the learning and teaching of science.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Lake Geneva, WI.

Cohen, E. G. (1991, April). *Classroom Management and Complex Instruction.* Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

Cohen, E. G., DeAvila, E. A., Navarette, C., & Lotan, R. (1988). *Finding Out/ Descubrimiento Implementation Module.* Stanford, CA: Program for Complex Instruction.

Cohen, E. G., Intili, J. K., & Robbins, S. H. (1979). Task and authority: A sociological view of classroom management. Paper published in *Seventy-eighth Yearbook of the National Society for the Study of Education.* Chicago, IL: The Society.

Cohen, E. G., & Lotan, R. A. (1990, July). *Beyond the workshop: Conditions for first year implementation.* Paper presented at International Association for the Study of Cooperation in Education. Baltimore, MD.

Cohen, E. G., & Lotan, R. A. (1991). *Producing Equal-Status Interaction in the Heterogeneous Classroom.* Stanford, CA: Program for Complex Instruction.

Cohen, E. G., Lotan, R., & Catanzarite, L. (1986, March). *Treating status problems in the cooperative classroom.* Paper presented at the American Educational Research Associations Annual Meeting, San Francisco, CA.

Cohen, E. G., Lotan, R. A., & Leechor, C. (1989). Can classrooms learn? *Sociology of Education, 62*(4), 75-94.

Comes-Diaz, L. (1984). Content themes in group treatment with Puerto Rican women. *Social Work with Groups, 7*(3), 75-84.

Cooper, M. G., & Morey, A. I. (1989). *Developing Thoughtful Practitioners through School/University Collaboration.* Washington, DC: American Association of State Colleges and Universities.

Cortez, C. P. (1986, March). *Minority Families Preventing Child Abuse and Neglect Through Parenting Education.* Paper presented at the Eterna International Society for Research in Parenting Annual Parenting Symposium, Philadelphia, PA.

Costantino, G., Malgady, R. G., & Rogler, L. H. (1988). Folk hero modeling therapy for Puerto Rican adolescents. *Journal of Adolescence, 11*(2), 155-165.

Cummins, J. (1979). Linguistic interdependence and the educational development of bilingual children. *Bilingual education paper series*. No. 2. Los Angeles: National Dissemination and Assessment Center.

Cummins, J., & Swain, M. (1986). *Bilingualism in Education: Aspects of Theory, Research and Practice*. New York: Longman.

Czerniak, C., & Chiarelott, L. (1985). Science anxiety among elementary school students: Equity issues. *Journal of Educational Equity and Leadership, 5*, 291-308.

DeAvila, E. A., Duncan, S. E., & Navarette, C. (1987). A few thoughts about language assessment: The Lau decision reconsidered. *Bilingual Education Paper Series, 1*(8). Los Angeles, CA: CSU Evaluation, Dissemination and Assessment Center.

Driver, R., & Bell, B. (1986). Students' thinking and the learning of science: A constructivist view. *School Science Review, 67*, 443-456.

Driver, R., & Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science Education, 13*, 105-122.

Dunbar, L. H. (1980). *The ulitization of values clarification in multicultural education as a strategy to reduce prejudicial attitudes of eighth grade students*. Unpublished doctoral dissertation, Northern Arizona University, Flagstaff.

Dwyer, F. M. (1978). *Strategies for Improving Visualization*. State College, PA: Learning Services.

Ehindero, O. J. (1980). The influence of two languages of instruction on students' levels of cognitive development and achievement in science. *Journal of Research in Science Teaching, 17*(4), 283-288.

Elementary Grades Task Force of the California Department of Education (1992). *It's Elementary! Elementary Grades Task Force Report*. Sacramento, CA: California Department of Education.

Entwistle, N., & Duckworth, D. (1977). Choice of science courses in secondary school: Trends and explanation. *Studies in Science Education, 4*, 63-82.

Flora, C. B. (1980). Women in Latin American fotonovelas: From Cinderella to Mata Hari. *Women's Studies International Quarterly, 3*, 95-104.

Fradd, S., & Hallman, C. L. (1983). Implication of psychological and educational assessment and instruction of culturally and linguistically different students. *Learning Disability Quarterly, 6*(4), 468-478.

Garcia, R. L. (1980). Instructional models for multiethnic education. In H.P. Baptiste, M.L. Baptiste, & D.M. Gollnick (Eds.), *Multicultural Teacher Education: Preparing Educators to Provide Educational Equity* (pp. 109-125). Washington, DC: Commission on Multicultural Education, American Association of Colleges for Teacher Education.

Gay, G. (1983). Why multicultural education in teacher preparation programs. *Contemporary Education, 54*(2), 79-85.

Gilbert, S., & Gay, G. (1985). Improving the success in school of poor black children. *Phi Delta Kappan, 66*, 133-137.

Giles, R. (1977). *The West Indian Experience in British Schools*. London: Heinemann.

Givens, S. (1982). Teacher education in multicultural settings. *Journal of Teacher Education, 33*(6), 52-55.

Grant, C. A. (1981). Education that is multicultural and teacher preparation: An examination from the perspectives of preservice students. *Journal of Educational Research, 75*(2), 95-101.

Green, L. (1982). Minority students' self-control of procrastination. *Journal of Counseling Psychology, 29*(6), 636-644.

Halpern, D. F., Hansen, C., & Riefer, D. (1990). Analogies as an aid to understanding and memory. *Journal of Educational Psychology, 82*(2), 298-305.

Harlen, W. (1985). Girls and primary-school science education. *Prospects: Quarterly Review of Education, 15*, 553-564.

Harris, G. A. (1985). Consideration in assessing English language performance of Native American children. *Topics in Language Disorders, 5*(4), 42-52.

Healy, J. M. (1990). *Endangered minds: Children's learning in today's culture*. New York: Simon and Schuster.

Herber, H. L. (1978). *Teaching Reading in Content Areas*. Englewood Cliffs, NJ: Prentice-Hall.

Hill, J. H., & Browner, C. (1982). Gender ambuguity and class stereotyping in the Mexican fotonovela. *Studies in Latin American Popular Culture, 1*, 43-64.

Hill, O. W., Pettus, C., & Hedin, B. A. (1990). Three studies of factors affecting the attitudes of blacks and females toward the pursuit of science and science-related careers. *Journal of Research in Science Teaching, 27*(4), 289-314.

Hochel, S. S. (1983, November). *A Position Paper on Teaching the Acquisition of the Mainstream Dialect in Kindergarten and Elementary School*. Paper presented at the Annual Meeting of the Speech Communication Association, Washington, DC.

Horn, M. (1983). Recent Mexican scholarship on comics. *Studies in Latin American Popular Culture, 2,* 208-212.

Hvitfeldt, C. (1986). Traditional culture, perceptual style, and learning: The classroom behavior of Hmong adults. *Adult Education Quarterly, 36*(2), 65-77.

Jeffcoate, A. (1979). *Positive Image: Towards a Multicultural Curriculum.* London: Chamleon.

Jegede, O. J., & Okebukola, P. A. (1992). Differences in sociocultural environment perceptions associated with gender in science classrooms. *Journal of Research in Science Teaching, 29*(7), 637-648.

Kahle, J. B. (1985). Minority women: Conquering both sexism and racism. In J.B. Kahle (Ed.) *Women in science* (pp. 102-123). Philadelphia, PA: Falmer.

Karlin, M., Coffman, T. L., & Walter, G. (1969). On the fading social stereotypes: Studies in three generations of college students. *Journal of Personality and Social Psychology, 13,* 1-16.

Kessler, C., & Quinn, M. E. (1980). Bilingualism and science problem-solving ability. *Bilingual Education Paper Series, 4,* 1-30.

King, J. E. (1991). Dysconscious racism: Ideology, identify, and the miseducation of teachers. *Journal of Negro Education, 60*(2), 133-146.

Knight, G. P., & Kagan, S. (1977). Acculturation of prosocial and competitive behaviors among second- and third-generation Mexican-American children. *Journal of Cross-Cultural Psychology, 8,* 273-284.

Koopmans, M. (1987). Formal school and task familiarity. *Cognition, 27,* 109-110.

le Boterf, G. (1984). The challenge of mass education in Nicaragua. *Quaternaire Education, 65/68,* 247-266.

Levine, D. U., & Eubanks, E. E. (1990). Achievement disparities between minority and nonminority students in suburban schools. *Journal of Negro Education, 59*(1), 186-194.

Levine, E. (1976). Teaching painting in a multi-age group. *School Arts, 76*(8), 13-20.

Longstreet, W. (1978). *Aspects of Ethnicity.* New York: Teachers College Press.

Lotan, R. A., Swanson, P. E., & LeTendre, G. K. (1991). *Detracking the Middle Schools: Curriculum, Instructional Strategies, and Access to Learning.* Palo Alto, CA: Stanford University.

LoPresti, P. L. (1985). *Bilingual and Multicultural Education: A Personal Prespective.* Washington, DC: Department of Education.

Mahan, J. M., & Lacefield, W. E. (1982). Employability and multi-cultural teacher preparation. *Educational Research Quarterly, 7*(1), 15-20.

Mangan, K. S. (1991). Colleges offer cultural-awareness programs to help professors understand needs of minority students. *Chronicle of Higher Education, 37*(25), 11-12.

Marrett, C. B. (1981). *Minority females in high school mathematics and science* (NIE report on the Program on Student Diversity and School Processes). Madison, WI: Wisconsin Center for Education Research.

Mason, C. L., & Barba, R. H. (1992). Equal opportunity science. *The Science Teacher, 59*(5), 22-25.

McDowell, C. L. (1990). The unseen world: Race, class, and gender analysis in science education. *Journal of Negro Education, 59*(3), 273-291.

National Science Teachers Association Board of Directors (1991, July). *An NSTA Position Statement: Multicultural Science Education.* Washington, DC: author.

Novak, M. (1971). *The Rise of the Unmeltable Ethnics.* New York: Macmillan.

Oakes, J. (1990). Multiplying Inequalities: *The Effects of Race, Social Class, and Tracking on Opportunities to Learn Mathematics and Science.* Washington, DC: Rand Corporation.

Olson, D. R. (1986). The cognitive consequences of literacy. *Canadian Psychology, 27*(2), 109-121.

Olson, D. R., & Torrance, N. (1987). Language, literacy, and mental states. *Discourse Processes, 10,* 157-167.

Ornstein-Galicia, J. L., & Penfield, J. (1981). A problem-solving model for integrating science and language in bilingual/bicultural education. *Bilingual Education Paper Series, 5,* 1-22.

Ortiz, A. A., & Maldonado-Colon, E. (1986). Recognizing learning disabilities in bilingual children: How to lessen inappropriate referrals of language minority students to special education. *Journal of Reading, Writing, and Learning Disabilities International, 2*(1), 43-56.

Ortiz, F. I. (1988). Hispanic-American children's experiences in classrooms: A comparison between Hispanic and Non-Hispanic children. In L. Weis. (Ed.), *Class, race, and gender in American education* (pp. 63-85). New York: SUNY Press.

Pang, V. O. (1988). Ethnic prejudice: Still alive and hurtful. *Harvard Educational Review, 58*(3), 375-379.

Patchen, M. (1982). *Black-White contact in schools: Its social and academic effects.* West LaFayette, IN: Purdue University Press.

Payne, C. (1980). The integration of multicultural education into thegeneral preparation of teachers. *Viewpoints in Teaching and Learning*, *56*(1), 77-87.

Pearson, W., Jr., & Bechtel, H. K. (1989). *Blacks, science and American education*. New Brunswick, NJ: Rutgers University Press.

Pitman, M. A. (1989). *Culture acquisition: A holistic approach to human learning*. New York: Praeger.

Philipp, R. A., Armstrong, B. E., & Bezuk, N. S. (1992). *A Study of Miss P.: An elemplary student teacher learning to teach mathematics in a cognitively guided manner*. Unpublished manuscript, San Diego State University, Center for Research in Mathematics and Science Education, San Diego.

Philipp, R. A., Flores, A., Sowder, J. T., & Schappelle, B. (1992). *Reflective practitioners of mathematics teaching*. (Available from National Center for Research in Mathematical Sciences Education, grant funded by the Office of Educational Research and Improvement of the U.S. Department of Education, Madison, WI).

Powell, L. (1990). Factors associated with underrepresentation of African Americans in mathematics and science. *Journal of Negro Education*, *59*(3), 292-298.

Raizen, S. A. (1991). The state of science education. In S.K. Majumdar, L.M. Rosenfeld, P.A. Rubba, E.W. Miller & R.F. Schmalz (Eds.), *Science Education in the United States: Issues, Crises and Priorities* (pp. 25-45). Phillipsburg, NJ: The Pennsylvania Academy of Science.

Ramirez, A. G., & Messick, D. R. (1976). *Language Attitudes and the Achievement of Bilingual Pupils, Research and Development Memorandum No. 146*. Palo Alto, CA: Standford Center for Research and Development in Teaching.

Ramirez, M., & Castaneda, A. (1974). *Cognitive strategy research: Educational applications*. New York: Springer-Verlag.

Reed, M. (1991). Videodiscs help American Indians learn English and study heritage. *T.H.E.(Technological Horizons in Education) Journal*, *19* (3), 96-97.

Rex, J., & Tomlinson, S. (1979). *Colonial Immigrants in a British City: A Class Analysis*. London: Routledge and Kegan Paul.

Rhodes, R. W. (1988). Holistic teaching/learning for Native-American students. *Journal of American-Indian Education*, *27*(2), 21-29.

Rodriguez, I., & Bethel, L. J. (1983). An inquiry approach to science/ language teaching. *Journal of Research in Science Teaching*, *20*, 291-296.

Roehler, L. R., & Duffy, G. G. (1989). The content area teacher's instructional role: A cognitive mediational view. In D. Lapp, J. Flood, & N. Farnan (Eds.), *Content area reading and learning: Instructional strategies* (pp. 115-124). Englewood Cliffs, NJ: Prentice Hall.

Roth, W. M. (1990, April). *Collaboration and constructivism in the science classroom.* Paper presented at the Annual Meeting of the American Educational Research Association, Boston, MA.

Sadker, M. P., & Sadker, D. M. (1979). *Beyond pictures and pronouns: Sexism in teacher education textbooks.* Washington, DC: Women's Educational Equity Act Program of US Department of Health, Education, and Welfare.

San Diego City Schools (1982). *An Exemplary Approach to Bilingual Education: A Comprehensive Handbook for Implementing an Elementary Level Spanish-English Language Immersion Program.* San Diego, CA: San Diego City Schools.

Schick, F. L., & Schick, R. (1991). *Statistical Handbook on US Hispanics.* New York: Oryx.

Shade, B. J. (1979). *Racial Preferences in Psychological Differentiation: An Alternative Explanation for Group Differences.* Madison, WI: Research and Development Center for Individualized Schooling.

Shade, B. J. (1982). Afro-American cognitive style: A variable in school success. *Review of Educational Research, 52*, 219-244.

Sims, W. E. (1983). Preparing teachers for multicultural classrooms. *Momentum, 14*(1), 42-44.

Sleeter, C. E., & Grant, C. A. (1987). An analysis of multicultural education in the United States. *Harvard Educational Review, 57*(4), 421-444.

Sless, D. (1984). Visual literacy: A failed opportunity. *ECTJ, 32*(4), 224-228.

Spring, D. (1950). Awareness of racial differences of preschool children in Hawaii. *Genetic Psychology Monographs, 41*, 214-270.

Stewart, D. A., & Benson, G. (1988). Dual cultural negligence: The education of Black deaf children. *Journal of Multicultural Counseling and Development, 16*(3), 98-109.

Suzuki, B. H. (1984). Curriculum transformation for multicultural education. *Education and Urban Society, 16*, 294-322.

Tanner, L. N., & Lindgren, H. C. (1971). *Classroom teaching and learning: A mental health approach.* New York: Holt, Rinehart and Winston.

Tobin, K., Tippins, D., & Hook, K. (1992, March). *Critical Reform of the Science Curriculum: A Journey from Objectivism to Constructivism.* Paper presented at the annual meeting of the National Association of Research in Science Teaching. Boston, MA.

"Total Enrollment in Institutions of Higher Education, by Race or Ethnicity of Student and by State and Territory: Fall 1988." In *Editor Digest of Educational Statistics, 1990* (p. 201). Washington, DC: National Center for Educational Statistics.

Valle, R. (1978). The development of a polycultural social policy curriculum from the Latino perspective. In D.G. Norton (Ed.), *The dual perspective: Inclusion of ethnic minority content in the social work curriculum* (pp. 58-79). New York: Council on Social Work Education.

Van Otten, G. A., & Tsutsui, S. (19483). Geocentrism and Indian education. *Journal of American Indian Educaiton, 22*(2), 23-27.

Van Sertima, I. (1986). *Blacks in science: Ancient and modern*. New Brunswick, NJ: Transaction Books.

VanTassel-Baska, J., Patton, J., & Prillaman, D. (1989). Disadvantaged Gifted Learners At-Risk for Educational Attention. *Focus on Exceptional Children, 22*(3), 1-15.

Verhoeven, L. T. (1987). Literacy in a second language context: Teaching immigrant children to read. *Educational Review, 39*(3), 245-261.

Vygotsky, L. S. (1962). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

Watson, S. B. (1991). Cooperative learning and group educational modules: Effects on cognitive achievement of high school biology students. *Journal of Research in Science Teaching, 28*(2), 141-146.

Watts, S. (1986). Science education for a multicultural society. In R.K. Arora & C.G. Duncan (Eds.), *Multicultural education: Towards good practice* (pp. 135-160). London: Routledge & Kegan Paul.

Weisner, T. S., Gallimore, R., & Jordan, C. (1988). Unpackaging cultural effects on classroom learning: Native Hawaiian peer assistance and child-generated activity. *Anthropology and Education Quarterly, 19*(4), 327-353.

Wheatley, G.H. (1991). Constructivist perspectives on science and mathematics learning. *Science Education, 75*(1), 9-21.

Williams, H., Fast, J., Berestiansky, J. Turner, C.W., & Debreuil, L. (1979). Designing science lessons to promote cognitive growth. *The Science Teacher, 46*, 26-29.

Woerner, J. J. (1988). The use of neuro-linguistic programming model for learning success. *School Science and Mathematics, 88*(6), 516-524.

Chapter 7

Reflections on the Role of Teacher Education in Science Curriculum Reform

Dorian Barrow
Kenneth Tobin

Reform is a process that requires systemic change to be initiated and sustained throughout a culture. Too often, however, reform tends to be something done to someone else, and too often perpetrators of reform have not undertaken thorough analyses of what is happening and the reasons for what is happening. Indeed, it is frequently accepted that there is only one valid description of what is happening, one best recommended course of corrective action, and one desirable final state. The world of reform can be grossly over-simplified. As the history of educational reform efforts increases, we learn a great deal about what does not work; yet, our culture retains the sacred myths that permeate the traditional underpinnings of our decisions. The folly of top down reform has been demonstrated adequately over time, and as the waves of reform continue to break on threatening shores, concessions are given in the shape of new approaches to reform that grant autonomy to teachers (who usually are required to change most). But what is the nature of the autonomy given to teachers? Do they have a meaningful voice in the present day reforms of science curricula? For example, since 1983 there have been many reports advocating reforms in K-12 science and mathematics (National Science Teachers Association [NSTA], 1983, 1989; National Council of Teachers of Mathematics [NCTM], 1989). These reports usually represent the views of relatively few, making suggestions for a vast majority, most of whom do not accept the basic premise that personal learning and change are necessary requisites for successful curricular change.

A close look at reform notions in science education suggests a high level of agreement on what ought to be done. Essentially, the science education community would like to see students learn science as a process, in ways that are meaningful and enriching, and enable citizens to interpret their worlds in terms of science. The National Science Teachers Association, through its report *Essential Changes in Secondary Science: Scope, Sequence and Coordination* (NSTA, 1989), advocated an integrated approach to science, beginning in a formal sense at grade seven and becoming increasingly abstract in the later high school years. The emphasis is on understanding science. Although few teachers would argue with the findings of the report, it ought to be pointed out that the main tenets of what is being proposed were formulated by a handful of influential persons within NSTA. Most teachers, who are being asked to effect changes in a particular way, did not have a voice in these recommendations for change.

Traditional views of curriculum support a commonly held perspective on state schooling and society that expertise and control reside within central governments, educational bureaucracies, or the university community. They treat as separate the worlds of theory and schooling as practice. In this world view it is curriculum planners who set the parameters, prescribe and manage, and effectively disenfranchise the people intimately connected with the day-to-day social construction of curriculum and schooling. We reject the view of curriculum as prescription (Stenhouse, 1967) which assumes that we can dispassionately define the main ingredients of science or educational methods courses of study and then proceed to teach the various parts and sequences in a systematic manner. Not only has the traditional view of curriculum been found to be simplistic and crude, but it also lacks explanatory potential and perpetuates what Goodson (1990) calls "the objectives game."

Breaking with the tradition of viewing curriculum as prescription occurs at least at three levels, and considerable adaptations are required for a successful transition. At one level is the need to change one's perspective from the traditional psychological, philosophical, technical, or scientific models of curriculum to one where curriculum is viewed as social construction. One major problem with the traditional models of curriculum is that"...these perspectives have been criticized recurrently because they do violence to the practical essentials of curriculum as conceived of and realized" (Goodson, 1990, p. 299). Furthermore, the curriculum when developed from the technical perspective adopts a management model of human interactions and treats the act of educating a human being as if it were the same endeavor as producing an artifact. These traditional ways of thinking about science and science education curricula also impact at the levels of process and practice.

At the process level the traditional modes of conceptualizing curriculum locate the act of creating a curriculum in a place and by people very different from where the curriculum is implemented and for whom the curriculum is intending to effect. In confronting this problem our efforts to restructure the science courses for prospective elementary teachers were initiated by acts that created development teams which provided an environment for planning. Development teams were comprised of scientists, a person in the field of the history and philosophy of science, science educators, and eventually also prospective and practicing teachers. This group discussed, argued, and ultimately reached compromises on visions of what such science courses should be, how they should be taught and by whom, what content should be included in the course, the textbooks to be used, and how learning should be evaluated. The development team comprised those with an interest in improving the quality of teaching of science courses for prospective teachers and embodied the multiple cultures of the university. This approach to curriculum design and implementation was successful in part because it was evolutionary rather than revolutionary. The curriculum commenced with extant beliefs and associated practices of the team members and, as a result of negotiations, an intended curriculum evolved that was legitimated though interactions among a group of individuals that, broadly speaking, represented the participants in the relevant educational culture.

What is intended invariably is not what is achieved. At the level of practice in the traditional ways of thinking about curriculum, the worlds of prescriptive rhetoric and schooling as practice remain apart. They both co-exist with one group, the curriculum prescriber, disproportionately benefiting from the coexistence. The teachers and students who are intimately connected to the daily construction, negotiation, and renegotiation of the curriculum become disenfranchised and disconnected from the planners and the process of change at a level of prescription. In attempts to reform the content preparation of prospective science teachers at Florida State University, the intended curriculum is conceptualized as being in a dialectical relationship with the implemented curriculum. One is seen to inform and provide critical support for the other.

Tobin and Jakubowski (1992) identified three cognitive requisites for meaningful curricular change: (a) a commitment to personal change, (b) a vision of what the curriculum can be like and how it can be represented in classrooms, and (c) opportunities to reflect in and on action, preferably with one or more colleagues. According to Tobin and Jakubowski, teachers should collaborate with others to plan and initiate curricular changes with the goal of enhancing student learning. We envision teams of educators collaborating to construct a vision that takes account of what is happening at the present time and builds from there to a desirable end point that is attainable within a time frame that makes sense within the context in which changes are to occur. The vision should be negotiated, that is different points of view should be discussed and a consensus argued between the persons involved in the reform of science curricula. Such an approach to change has the potential to address the conservative forces to change which inevitably act in a direction to sustain traditional practices.

A teacher's personal commitment to learn and change is a necessary but insufficient condition for reform. A goal that is common to the three projects reviewed in this chapter is to give teachers voice by supporting them in developing their knowledge of science teaching and learning. Betty Castor, Florida's Commissioner of Education, emphasized the central role teachers play in the reform effort. She stated, "Teachers are the key to successful restructuring of our science education program in Florida. We are looking for total involvement." (Castor, 1992, p. 4). However, strategies for involving participants and giving them voice vary in the three projects. Of critical importance are the relative power relationships among those involved in efforts to change curricula and a question that ought to be addressed is whether or not those who are required to change have autonomy with respect to the nature of the changes that are needed and the methods to be employed in implementing and sustaining those changes.

Teachers cannot change in isolation of the culture in which the curriculum is to be implemented. Any changes introduced by a teacher soon impact others who might or might not have a commitment to adapt their roles and associated actions. Efforts to resist change and maintain the status quo are not unusual, and those who initiate change often need support. For this reason it makes little sense to mandate change from outside without having access to the particular settings in which reform is attempted. The three initiatives that are discussed in this chapter endeavored to empower those involved in the reform of science education. The analyses of the attempts to change the manner in which science courses for prospective elementary teachers are taught and learned, and the establishment of three professional practice schools provide insights into the issues that need to be addressed if Florida's attempts at systemic and sustained reform are to be successful. What follows is a description of the initiatives, and a discussion of what we have learned about the process of initiating and sustaining systemic reform.

SCIENCE LEARNING OF PROSPECTIVE ELEMENTARY TEACHERS

With the assistance of the National Science Foundation, an interdisciplinary group at The Florida State University planned to reform the approach to the teaching and learning of science for prospective elementary teachers within the university. The three-year project involves the development of new courses in physics, chemistry, geology, and biological sciences in the first year. These four courses were selected initially because of the way science is organized within the College of Arts and Sciences in the university. In the present year, those responsible for planning and implementing the physics and chemistry courses in the first year worked together to develop a new course in physical sciences, those who had developed the geology course collaborated with colleagues from oceanography and meteorology to develop an earth sciences course, and the biology course was taught for the first time. In the third year the three integrated science courses (i.e., physical, earth and biological) will be modified and taught. Thus, at the end of the project, three four-hour courses for prospective elementary teachers will have been planned, implemented, and revised.

One of the distinguishing features of this attempt at reform was that scientists, science educators, teachers, and prospective teachers from the outset were provided resources and asked, as in kind support, to create some time to devote to a process of constructing a sense of community and collegiality. This was given considerable priority and was done mainly through development team meetings, sessions at professional practice school sites, and an on-going seminar series in which both scientists, science educators and graduate students presented positions on issues related to science, teaching, learning, teacher education, science in public schools, or epistemology.

We share with Stenhouse (1967) the view that it is teachers who, in the end, will initiate and sustain the reform of curricula. The approach to curriculum change in the project was to begin with the beliefs of those who would ultimately teach the courses. For example, in the development of a new physics course we established a course development team that included the professor who would teach the course and the teaching assistant. We commenced with the beliefs of members of the course development team and gave highest priority to those of the professor who would teach the course. Hence, curriculum development becomes a process of translating ideas into classroom practices and, in this case, assisting prospective teachers to learn by systematically and thoughtfully testing ideas (Goodson, 1990).

Rather than commence with programs that had been developed elsewhere, we decided to commence with what was presently happening at Florida State, and involve a large group of stakeholders in the negotiation of a revised curriculum. For example, the restructured physics course for prospective elementary school teachers was constructed, negotiated, and renegotiated as it was being implemented in the spring semester of 1992. The course development team consisted of the instructor, the teaching assistant, four professors from the physics department, a science historian, two chemists, two science educators, and a prospective elementary school teacher enrolled in the course. The team met once every two weeks. The person who assumed responsibility for the course was, in one role, one of 10 people contributing equally to the planning of a new physics course; in another, he was one of two people who translated those plans into teaching and learning activities, and yet in another role he was the person who implemented the curriculum in the physics classroom.

While the physics course was being taught, there were several events that contributed to the learning of those who were interested in teaching science courses for prospective science teachers. A seminar series featuring speakers from within and outside of the university took place at a frequency of once every two weeks. The seminar dealt with topics such as constructivism, constructivist perspectives on teaching college science, an analysis of the science courses taken by prospective elementary teachers, an evaluation of traditional approaches to college science, and an analysis of trends in science teaching in Florida. In addition, in the same period of time chemistry and earth sciences courses, to be taught in the summer, were planned by course development teams. A similar process continued into the fall of 1992 when a biological science course was taught at the same time as physical and earth science courses were planned. The approach assumes that individuals learn and change as a result of teaching new courses, but also as a result of negotiating with others within the cultural context, about what has happened, what appears to succeed, and what does not appear to succeed. Intensive analyses of videotapes of courses implemented in the spring and summer of 1992 also have provided a basis for the reflection of those who taught the courses and all of those who are involved in the planning and implementation of the new courses.

Incrementally, a new culture is evolving, one that began with traditional practices, and has evolved based on frequent opportunities for the participants to reflect on what has happened and negotiations between the stakeholders, not just with respect to one course, but to all of the new courses. The approach has been adaptive rather than revolutionary; however, we expect change to be on-going and supported by a significant multidisciplinary faculty that pervades the College of Arts and Sciences, and the College of Education.

LEARNING TO TEACH SCIENCE

Two essential components of our approach to learning to teach science is that activities must begin with what is known already and ought to be grounded in the situations in which science curricula are implemented. The challenge of the first requisite is that strategies must be adopted to enable prospective teachers to put voice to their knowledge and to negotiate what makes sense to them with peers, classroom teachers, and university science educators. The multitude of ways of addressing this challenge are not the focus of this chapter, but all show concern for each learner being able to connect his or her own knowledge to the curricular activities, create perturbations, and pursue viable resolutions to problems that arise in the process of learning. Because of the personal and social aspects of learning with understanding, it seems essential that prospective teachers have considerable autonomy with respect to their involvement in activities designed to promote their learning to teach science.

The second requisite has been addressed in a number of ways that include the use of videotaped and written vignettes of teaching, critical analyses based on direct observations of teaching, and reflection on personal teaching of individuals, small groups and intact whole-class groups. Activities such as these provide situations into which prospective teachers can project themselves in a process of connecting what they know to curricular contexts. To the extent possible, prospective teachers need opportunities to test the viability of knowledge in the situations they encounter. Accordingly, a diverse set of experiences needs to be encountered to see what knowledge is potentially generalizable across contexts and the situation-specific nature of much of what we know about the teaching and learning of science.

An integral part of our attempt to reform science education courses at Florida State University has involved the development of a professional practice community involving faculty and students from three public schools, and faculty and prospective teachers from the College of Arts and Sciences and The College of Education. A professional practice community is one where the principal foci are on learning. Individuals within the community collaborate to enhance the learning of one another. The three schools involved in the community are an elementary, middle, and high school that have a feeder relationship with respect to one another, and generally draw on students from families of low socioeconomic status. In each of the three schools the teachers agreed to be involved in a collaborative arrangement with one another and with Florida State University. The details of that arrangement evolved as interested faculty began to interact with members of the university team.

Pre-interns and interns were involved in at least one of the professional practice sites in a variety of ways that included observations of teaching, assisting teachers with tasks such as grading papers, setting up and tidying away laboratory equipment, supervising small groups of learners, teaching individuals, small groups and intact classes, and assisting the teacher to plan lessons. By locating the methods course at a school campus, the pre-interns had ready access to classes and were able to schedule observations, in-class experiences, and discussions with teachers and students with relative ease.

Faculty and graduate students from Florida State University arranged to visit the classroom of one or more teachers on a planned basis. The purposes of the visits were negotiated with teachers and included observing, undertaking collaborative research, providing assistance with aspects of the curriculum, and obtaining data for use in later meetings with the teacher to facilitate reflection. A range of activities at the school included workshops on science content and teaching methodology, reading seminars, meetings to negotiate goals and discussions of progress toward those goals, and potential collaboration in research projects.

Our philosophy with respect to the professional practice sites was to construct ourselves as learners. We were aware of the knowledge we had that might benefit the school curriculum, but we were also aware that there was a great deal we could learn from the teachers and students in the schools. As requested we were prepared to act as resources and facilitators for teacher learning and curriculum change within the schools, but unless our input was solicited we were prepared to focus on our own learning and establishing environments that were conducive to the learning of everyone in the community. We were careful not to construct ourselves as experts with all of the answers to the problems in the professional practice schools and to maintain a position of being co-learners, endeavoring to find out what was happening and the reasons for what was perceived to be happening. Accordingly, we were in a good position to provide assistance when requests were made because our suggested solutions would take account of characteristics of the extant curriculum.

FLORIDA'S REFORM OF SCIENCE EDUCATION

In 1988 the State of Florida initiated a program of systemic reform of science curricula with the establishment of a Task Force to develop a comprehensive plan to improve mathematics, science and computer education in Florida's schools. The Task Force consisted of leaders from the business and educational communities throughout the state. For a year and a half the group met, listened to a multitude of evidence about changes that were needed, and formulated a *Comprehensive Plan* (Florida Department of Education, 1989) which took the form of a set of goals and associated rationale. To provide insights into some perspectives on the operation of the Task Force the following excerpt is provided from a paper by the second author (Tobin, 1992), who was a task force member representing the educational community:

> Meetings of the Task Force occurred in hotels in the major cities of the state. A lasting memory was the way that the members of the Task Force were seated around the sides of a rectangle open at one end. At that end, and at least 10 meters

> back were rows of seats, set up for spectators. In addition, there were seats around the periphery of the room for those who wished to sit there. These seats were often used by supervisors from the state department of education who were not a part of the Task Force. The overall result was to set up a center/periphery effect. Those on the periphery, ironically, would be those who later would have to implement the recommendations of the Task Force. The center/periphery effect was noticeable in other ways as well. Only those on the Task Force, or those invited specially to address it were able to contribute to the proceedings. The nature of the deliberations of the Task Force set up a "broken system" metaphor where the Task Force searched for ways to improve an ailing educational system, often looking for the broken parts of the system. Those with the responsibility for the system were frequently seated at the periphery, feeling powerless to defend their positions, and angry at what they perceived to be unfair criticisms.

The issue of representation is important in terms of the composition of the Task Force and the extent to which constituencies with an interest in science education were given voice in the formulation of the recommendations for reform. Those who decided on the composition of the Task Force seemed to be aware of the importance of having broad representation from the educational and business communities, and they seemed equally aware of the significance of excluding others. A challenge that was not directly addressed by the Task Force was to relate the emerging reform agenda to what was happening at the present time and to the beliefs of those who would implement the recommendations for change. The Task Force was clear about its role in relation to formulating an agenda for reform and a viable plan for initiating and sustaining systemic improvement of science education. However, there was no plan to educate those who would ultimately implement the *Comprehensive Plan* or assist them to construct beliefs about the need for personal and systemic change.

A concern that ought to be addressed in future attempts at reform is how to deal with individuals and groups who, through their actions, appear to be marginalized. Why did individuals seated at the periphery sit in those places? Why did these individuals remain silent when they had strong points of view? How could the Task Force have provided a stronger voice to science educators and others with an interest in science education? Answers to such questions are not just for educational policymakers. It is apparent that many individuals in the community constructed themselves in a relatively disempowered state with respect to the mission of the Task Force. What prevented individuals from providing written and oral submissions on drafts of the *Comprehensive Plan*? Furthermore, it might also be productive to reflect on the significance of the observation that some members of the Task Force rarely spoke at meetings and many of those who did speak had little influence.

The recommendations of the *Comprehensive Plan* were revolutionary rather than adaptive. To what extent was there universal support for the eight goals of the *Comprehensive Plan*? A significant number of educators maintained that, contrary to the views expressed at meetings of the Task Force, practices in schools with which they were involved usually were exemplary. By these individuals, at least, the deliberations of the Task Force were not regarded as credible. Evidence presented to the Task Force was rarely grounded in thorough studies of what was happening in Florida, perceived needs of teachers, students and the community, or beliefs about the desired state for science education. If studies such as those implied above had been conducted, it would have been possible to recommend in such a manner that adaptations could be argued for those schools and classrooms where change was needed. Education on the need for change could be referenced to the data underpinning recommended changes.

The irony of the State's implementation effort was that those on the *periphery* during the formulation of the *Comprehensive Plan* were at the *center* of the implementation effort. Not surprisingly, they showed little ownership of the *Comprehensive Plan* and appear to have ignored it to the greatest extent possible. Their implementation efforts were reserved for reform efforts they believed in, and it seems as if they continued their duties just as they had prior to the acceptance of the *Comprehensive Plan* as policy. An evaluation of the implementation of the *Comprehensive Plan* revealed that little or no progress was made on five of the eight goals (Dana, 1992). Of most concern was the lack of attention to teacher education. The expectation seemed to be that policy would be mandated from above, accepted by school districts and the community, and implemented as intended by the teaching profession. The state effort appeared to be associated with distributing and disbursing funds provided by the legislature. Traditional methods, which were familiar to state level bureaucrats, were used just as they had been in the past. The additional funds available to be disbursed created a challenge which was seen in terms of distribution of resources. Education about the *Comprehensive Plan* was not a serious concern at any level. Notably, state level supervisors were not educated in relation to the *Comprehensive Plan* and efforts at reform were not coordinated within the bureaucracy.

We are not claiming that state level personnel did not do their best. On the contrary, many people worked long hours and did what they could to improve science education. Indeed, an elaborate structure was devised for implementing the *Comprehensive Plan*. One office was given the responsibility of implementing the *Comprehensive Plan* and an oversight committee consisting of business and educational leaders met to consider progress towards implementation. However, many offices in the state department were involved in implementing various components of the *Comprehensive Plan* and it was difficult to exercise a coordinated effort. The office with the responsibility of implementing the *Comprehensive Plan* did not have the authority to coordinate the initiatives of the many science, mathematics, and technology program offices involved. Dana (1992) noted that:

> As an example of the lack of coordination of programs that fall under the auspices of the *Comprehensive Plan*, out of 17 categorical programs in mathematics, science and technology funded for 1990-91, only two projects identified *Comprehensive Plan* goals as a justification for content or scope of program. Furthermore, each of those projects purported to serve different needs of the state. Yet, there was no way to determine to what extent they were effective because six had no evaluation component, five had process evaluation but no follow-up evaluation to assess impact on student learning, and only two included site visits to determine classroom impact as part of the evaluation. (p. 192)

Dana graphically illustrates that the ways of operating changed little within the Florida Department of Education, before and after the acceptance of the *Comprehensive Plan* as state policy. There was no "dominant coalition with the power or authority to fully implement the ideals of the *Comprehensive Plan*" (Dana, 1992, p. 194). The culture of the Florida Department of Education, as it pertained to science education, remained much the same. Accordingly, the support for change was largely confined to distributing funds that were redirected toward the implementation of the goals of the *Comprehensive Plan*.

A notable problem was lack of attention to district-wide teacher enhancement on issues incorporated in the *Comprehensive Plan*. Although districts appreciated additional resources for science, mathematics, and computer education there were few examples of comprehensive approaches to reform. Is it possible that districts did not support the goals of the *Comprehensive Plan* because they did not perceive a need for change? Did districts have a vision of what science education could be like for them if the *Comprehensive Plan* was implemented? In the absence of statewide programs to educate state and district level policymakers in relation to the need for and the nature of recommended changes it is little wonder that there have been few signs of reform.

The biggest problem we perceive at this time is failure to initiate reform of teaching and learning from the grassroots upward. How can teachers be assisted to examine classrooms through different lenses that allow them to see the need for the changes society expects and that permit them to map paths for change which emanate from present classroom practices? Can teachers be educated for a process of reform that is mutually adaptive in the sense that what happens in science classrooms is responsive not only to teachers' beliefs but to those of students and the local community as well? If we are successful in this goal, the paths to reform will be tortuous, the ideal state being much more differentiated than is evident in the *Comprehensive Plan*. Teachers would be responsible for adapting the curriculum in their own classes to fit better with the beliefs of the community at large, the resources available to support change, and the knowledge that accrues from on-going educational programs that are grounded in school-based learning.

One of the critical recommendations of the *Comprehensive Plan* was, as a matter of urgency, to reform elementary science. Accordingly, with the assistance of funds from the National Science Foundation Statewide Systemic Initiative Program, a five-year project known as *Discover Science in Florida* was implemented in 1991. The vision of the project is to restructure K-8 science education throughout the state using a teachers-teaching-teachers model. This approach recognizes the significance of teachers in the process of systemic reform and acknowledges that the science teaching profession has much to contribute to the education of its members. However, there is little evidence that the approach is adaptive. To what extent are teachers given voice in describing what they are presently doing and justifying their approach based on the constraints they face? What visions do teachers have for the future of science education in the state? The beliefs underlying extant practices and visions of what is ideal are the starting point for the learning of teachers and will not be disregarded in the process of learning and deciding how to implement the curriculum. Accordingly, the use of the teachers-teaching-teachers model should include opportunities for negotiation and consensus building in relation to what should be happening and how to best engineer appropriate paths leading from what is presently happening to the agreed upon ideal state.

To maximize coordination and support systems the state was divided into six regions, each with a regional coordinator. Most of the regional coordinators serve four field-test sites, and, together with district personnel and the school science teams, work to build consensus on the improvement school science programs. Regional coordinators are also instrumental in facilitating the evolution of district level science leadership whose principal role is to support the K-8 science restructuring effort and to help sustain systemic change at the district level. This approach incorporates procedures to overcome many of the problems identified by Dana (1992) in the initial attempts to implement the *Comprehensive Plan*. The regional approach allows the reform to be tailored to the needs of local communities and to give attention to the voices of teachers who are to initiate the reforms in their classrooms. The regional coordinators can also marshall resources from across the state to provide assistance to teachers as it is needed. The provision thereby exists for the approach to reform to be adaptive, to focus on education of the individuals involved in the reform effort, and to take account of the cultures into which changes are to be introduced.

District science leadership teams, made up of community leaders in education and business or institutional leaders (e.g., concerned with the environment, museums, zoos, etc.), are a significant component of a network support system. Through the efforts of leadership teams teachers are provided with materials for hands-on science or assistance in making contacts through the local regional network to resource people and science-rich institutions. Leadership teams are functioning in a multiplicity of roles including making recommendations to districts on policies for instruction, textbooks and assessment that are consistent with the over-arching goal of an experiential, hands-on approach to learning science.

School science teams are the vehicle for reform and are a critical component of the support network system. Each consists of two lead teachers and a principal from each participating elementary school. Twenty-five school teams have been established after Year 1 of the project and are currently participating in a host of activities that are advancing the reform agenda. For example, after a four-day Summer Academy, the school teams are now participating in follow-up seminars in leadership strategies, pedagogy, and science content. In addition, the teams are provided with opportunities for support and sharing. Teams are charged with refining their school science improvement plans based on the needs of their school and on the teachers' ideas and strategies for reform. School science teams are encouraged to reflect on the implementation of this restructured science learning approach and share their findings, experiences, and recommendations with other school teams so that the barriers to implementing a new program can be understood and overcome.

The summer academies, as mentioned above, are another avenue through which *Discover Science in Florida* will continue to provide network support to teachers in the field. At the first summer academies, for example, principals and teachers together examined the influence on existing practices of their beliefs about learning and teaching. They also identified obstacles to reform and developed strategies for becoming effective agents of change in their schools. Active engagement in such activities increases the probability that teachers and administrators will co-construct approaches to reform that take account of what is presently happening and what is possible, and the local constraints that will need to be addressed if the reform agenda is to be implemented as planned. Events such as the summer academies also provide further opportunities for teachers and principals to share experiences with peers from other schools throughout the state, enhancing collegiality while advancing the systemic reform agenda of the science program in a way that reflects what the people at the various sites have learned.

Even within such events as summer academies there are cultural phenomena that have to be addressed. What are the expectations of the participants? Do they come to an academy with the goals of learning from studies of their own practices and beliefs and forging new images of what is possible through interactions with colleagues and administrators from their own schools and across the state? Or do they construct themselves as disempowered learners waiting to be told about the latest trends in science education, how to adapt their classrooms to reflect what is the most desired state, and to be given the latest resources to be successful? Do they expect those implementing the academies to be experts with all of the answers to their problems and access to the resources needed to solve the problems? Do participants see their own personal learning and change as the essence of the reform process or do they see the efforts being dependent largely on the efforts of others? Questions such as these need to be asked and answered as *Discover Science in Florida* seeks to identify and implement approaches that have the potential to initiate and sustain pervasive reform in science education. Just as teachers in science classrooms have to learn to negotiate the goals of science learning with their students, so too do would-be reformers have to learn to negotiate the goals and roles of all participants in the process of reform.

CONCLUSION

In this chapter we have explored three efforts at the reform of science education within the State of Florida, each of which embraces a component of science teacher education. Even though these projects differed in terms of focus and scale, there were common elements that applied to each. From each project it is possible to see implications for the other. The most significant of these is the realization that systemic reform does not occur in isolation from complex socio-cultural factors that must be considered alongside the vision for reform. It will not be possible to change any part of a system in a given direction without taking account of extant practices and why those practices have been supported within the system. Revolution is unlikely to be successful in the sense that it is sustained over time. Rather, adaptation, based on education and research, appeals as a possible means of initiating and sustaining changes in the quality of science education.

Our efforts to change the science courses for prospective elementary teachers at Florida State University have highlighted the significance of the culture in sustaining traditional practices. Customs based on lecture and use of textbooks make sense to course instructors who have used them throughout their careers as students and teachers. Not surprisingly, they think not so much of the revolution of different ways of organizing students and the possibility of abandoning textbooks in favor of multiple resources but in terms of lecturing in different ways, of implementing laboratories differently, and of using different textbooks. Gradually, after several courses were planned and implemented, after numerous colloquia and many meetings of course development teams it is possible to see changes in the ways that the professors view teaching and learning college science. However, there is considerable variability within the group with whom we have worked. Where they are presently with respect to their beliefs and practices reflects, in large part, where they were at the beginning of the project. Each has adapted in a gradual process of reflection, negotiation, and consensus building. The process is educative, and it is clear that there is no one right way to teach science at this level for prospective elementary teachers. Accordingly, most of those involved in the project view themselves as learners with respect to teaching science to these students and are prepared to learn. In terms of power relationships there is little evidence of struggles; most see the others as equals even though faculty from different departments and colleges, graduate students, and undergraduate students are involved in the re-development of the courses.

The major challenge is to sustain the initiative after funding from the National Science Foundation ceases. The magnitude of the task comes into perspective when one considers that presently the project involves only a small number of faculty. The beliefs and practices of fewer than 10 faculty are showing significant changes, in ways that are likely to enhance the learning of prospective elementary teachers. In addition, 20 to 30 of their colleagues are now involved in parallel efforts to improve the quality of science learning within the university and in K-12 education in northern regions of the state. The question is whether or not a critical mass of faculty will influence colleagues within the university to change their beliefs and practices so that the changes will become systemic and sustained. We believe that unless a planned effort is made to extend the project to include remaining faculty, it is unlikely that the changes will spread and be sustained.

The schools involved in our professional practice communities are characterized by relatively high percentages of children with parents having low socioeconomic status, many of whom are African Americans. The middle and high schools have histories of disruptive students and low achievement levels in science compared to other schools in the district. We asked to be involved with these schools because we have observed a trend in Florida for an increased incidence of problems in schools with high proportions of students with Hispanic and African American ethnic backgrounds, especially with parents of low socioeconomic status. We felt that by being involved in such schools we would learn more about the problems that the State of Florida will encounter in trying to implement its agenda for enhancing the quality of science learning. Thus, the study of the professional practice community is a case study that ought to inform those involved in the *Discover Science in Florida* project.

One critical problem we have faced in the professional practice sites has been to effect changes in the learning environments. This is not so much a problem of teachers lacking vision, teachers having a commitment to personal change, or teachers feeling that there are no problems. On the contrary, teachers are motivated to learn, are aware of the problems they face, and endeavor to implement changes. The main problems are with the students. For at least a decade the culture of the schools we are involved with has supported practices that have allowed students to be disruptive and to challenge the authority of teachers. The climate does not seem conducive to giving students autonomy with respect to how and what they learn. Before any program of change can be initiated it is essential that the school community engage in a program in which goals are re-negotiated in the context of a new set of norms for behavior within the culture. Just as any society must have a set of rules to govern the actions of its participants, so it is necessary for our professional practice community to re-negotiate the rules of the community and procedures to enforce those rules in contexts where students have greater autonomy for their learning. Therefore, new roles need to be negotiated for teachers, students, and others who participate in the process of learning (e.g., parents, administrators). Teachers, students, administrators, and presumably parents, who have been accustomed to traditional approaches to science, will have difficulty understanding approaches such as those based on students actively constructing scientific knowledge through problem-solving in collaborative groups. If such approaches are to be initiated and sustained in a school, it will be necessary for all participants to understand the changes in relation to a vision of the new culture. When the participants of a culture understand the new vision and accept it as a goal to be accomplished, then it might be anticipated that cultural change will occur, and support for the new vision will be forthcoming from throughout the culture. In the absence of a clear vision of what the new culture will entail for all participants it is difficult to adapt existing practices and provide the support that is essential for initiating and sustaining change.

The systemic reform of science education in Florida can only be sustained if careful attention is given to a need to build new beliefs, practices, and customs from old beliefs, practices and customs. Some efforts to change will be thwarted, some will be successful, and for every step forward there might well be a half step backward. We have seen in our review of the three reform efforts that change can only occur when participants in a culture have a commitment to personal learning and change, when participants are able to construct a vision of what is possible and define for themselves new roles within that vision, and when opportunities are available for participants to examine what they are doing in relation to their goals and to resolve any discrepancies. If all participants become researchers of their personal roles in relation to the actions of others in the educational community, there is a possibility of an evolution occurring as the old give way to the new in a never-ending process of adaptive reform that has the potential to be both sustaining and systemic. In such a vision of reform, the metaphor of top down is no longer applicable and all participants have the power and autonomy to enact their roles, negotiate their goals, and learn accordingly. This vision is consistent with the State's current press to empower teachers (Castor, 1992). Here lies a paradox. Empowerment is not something that can be given to teachers or other participants in a culture. The fate of Florida's reform efforts in science education will not rest with policymakers in any direct way. If any of the projects described in this chapter are to be successful it will be necessary for all participants in the culture to get involved in collaborative processes that focus on learning, facilitation, and adaptation.

REFERENCES

Castor, B. (1992). Florida's statewide systemic initiative is targeted to the future. *Discover, 1*(1), 4.

Dana, T. M. (1992). *Achieving comprehensive curriculum reform: An analysis of the implementation of a mathematics and science education policy.* Unpublished doctoral dissertation. Tallahassee, FL: The Florida State University.

Florida Department of Education. (1989). *Florida's Comprehensive Plan for improving mathematics, science and computer education.* Tallahassee, FL: Florida Department of Education.

Goodson, I. F. (1990). Study curriculum: Towards a social constructionist perspective. *Journal of Curriculum Studies, 22*(4), 299-312.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: NCTM.

National Science Teachers Association. (1989). *Essential changes in secondary science: Scope, sequence and coordination.* Washington, DC: NSTA.

National Science Teachers Association. (1983). Recommended standards for the preparation and certification of teachers of science at the elementary and middle/junior high school levels. *Science and Children, 21*(1), 65-70.

Stenhouse, L. (1967). *Culture and education.* New York: Weybright and Talley.

Tobin, K. (1992, July). *The folly of top down reform.* Paper presented at an International Conference of Teaching and Learning Science and Mathematics at the National Changhua University of Education, Changhua, Taiwan.

Tobin, K., & Jakubowski, E. (1992). The cognitive requisites for improving the performance of elementary mathematics and science teaching. In Ross, E. W., Cornett, J. W., & McCutcheon, G. (Eds.), *Teacher personal theorizing: Connecting curriculum practice, theory and research.* (pp. 161-178). New York: Columbia University Press.

Chapter 8

A Model for Inservice Science Teacher Enhancement Through Collaboration of Rural Elementary Schools and Universities

J. Preston Prather

Widespread public concern about the condition of science education in the United States has generated intense pressure for reform (American Association for the Advancement of Science, 1989; American Council on Education and the Education Commission of the States, 1988; National Commission on Excellence in Education, 1983; National Science Teachers Association, 1990a, 1990b; U.S. Department of Energy, 1990). Whereas teacher-centered, subject-specific science instruction has been typical in the past, interdisciplinary or integrated curricular approaches and student-centered, activities-oriented teaching methods are now widely promoted. Clearly, the nation stands at the threshold of a new era in science education.

This chapter describes a collaborative effort of a university, state department of education, and 27 local school systems that culminated in a program model that helped thousands of local elementary teachers and principals prepare to respond to the challenge for change. The program was designed to prepare teams of teachers and principals from each participating school system and their system supervisor of instruction with the interdisciplinary science knowledge, activities-oriented teaching methods, inservice education skills, and leadership capability needed to plan and implement reforms, beginning in local classrooms. The resulting Collaborative Program Model is depicted in Figure 1.

It was anticipated that the model would provide immediate, direct benefits to participating schools through improvement of classroom instruction as indicated on the top section of Figure 1. Supervised field experiences in needs assessment and program planning were included to prepare the teams to plan and implement inservice education programs for their peers. The combination of academic and field preparation was intended to provide team members with the background and self-confidence to exercise long-range leadership through on-going inservice education and program planning and development. As indicated on the bottom portion of Figure 1, it was anticipated that the teams' leadership initiatives would extend to other school systems and help to involve businesses and community agencies in the quest for improvement of science teaching.

Ideally, recruitment of a network of teams from strategically located school systems within a state would provide a time- and cost-effective resource for grass-roots reform of elementary science teaching. Reforms would begin in the teams'

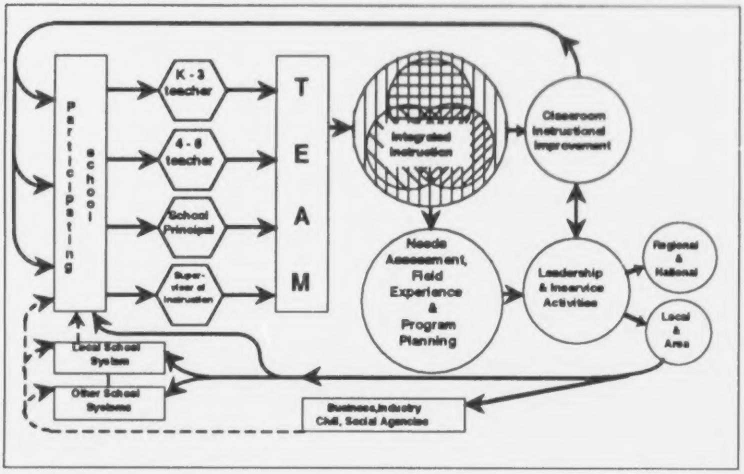

Participating school
K - 3 teacher
4 - 6 teacher
School Principal
Super-visor of Instruction
T E A M
Integrated Instruction
Classroom Instructional Improvement
Needs Assessment, Field Experience & Program Planning
Leadership & Inservice Activities
Regional & National
Local & Area
Local School System
Other School Systems
Business,Industry Civil, Social Agencies

Figure 1. The Collaborative Program Model

local school systems and extend across the state and beyond through a ripple effect of inservice education programs. The Collaborative Program Model produced this result as the teams conducted more than 330 programs directly serving more than 7,800 of their inservice peers over approximately three and one-half years. Project participants were invited to conduct inservice programs for school systems in five other states; and teams or team members presented more than 20 professional programs at regional and national meetings of teachers, including annual meetings of the National Science Teachers Association.

Significant gains in science performance were observed among students taught by participating teachers, compared to students in comparable situations taught by non-participating teachers. Although initially developed for reform of elementary science education in rural school systems, the Collaborative Program Model is readily adaptable for use in other subject areas, other grade levels, and non-rural locations.

THE RATIONALE FOR THE MODEL

Teacher education institutions have faced two major challenges as they attempted to respond to the increasing pressure for reform of education in general, and science education in particular. On the one hand, there was the problem of developing programs that would better prepare preservice teachers to handle the increasingly demanding task of classroom teaching. On the other hand, there were hundreds of thousands of inservice teachers who would need immediate additional preparation if they were to be equally prepared to meet the challenge of a changing educational environment.

After reviewing the type of preparation needed for classroom teaching, many institutions concluded that the task could not be accomplished in the traditional four-year teacher education program. Perhaps most notable of these is the Holmes Group (1986) of institutions that adopted five-year programs for teacher preparation. Discussions of the anticipated benefits of expanded preservice teacher education programs called attention to the potential benefits of additional preparation for inservice teachers, especially in the area of elementary science teaching.

All teachers want to do the best for their students, and programs that promise improved student performance are typically viewed with enthusiasm by inservice teachers. An excellent example of this is the growing interest in hands-on science teaching and constructivist learning concepts among inservice elementary teachers over the past decade.

Reporting on a synthesis of information from more than 100 research projects, Shymansky, Kyle, and Alport (1983) presented evidence that hands-on science programs were superior to traditional methods of science teaching. Wise and Okey's (1983) meta-analysis of effects of teaching strategies on student achievement, which involved 160 studies, indicated that use of concrete manipulatives in science instruction contributed to larger gains than typical fact-oriented, verbal teaching methods. Hands-on science experiences had become the top research interest among elementary teachers by the mid-1980s (Gabel, Samuel, Helgerson, McGuire, Novak, & Butzow, 1987). However, an accelerated reform effort in Tennessee escalated that interest to a level of critical concern for thousands of elementary teachers in that state.

In 1984, the Tennessee State Board of Education developed a new curriculum framework that mandated a hands-on science teaching approach for all grades K-12 (Field, 1988). Typically, relatively few elementary teachers majored in science in college. Most elementary teachers are generalists, required to teach all subjects. As a result, few elementary teachers have felt qualified to teach science (Shrigley, 1974; Weiss, 1978, 1987; NSTA, 1983), and poor attitudes have prevailed toward teaching science at that level (Pederson & McCurdy, 1992). Even many of the most seasoned elementary teachers felt uncomfortable with hands-on teaching methods, which are very different from the methods they had experienced in their own school and college science studies (Prather, Hartshorn & McCreight, 1988).

Time- and cost-efficient programs were needed to help inservice elementary teachers gain the interdisciplinary science content and instructional skills needed for the transition to hands-on/minds-on science teaching. The University of Tennessee at Martin's Center of Excellence for the Enrichment of Science and Mathematics Education (CEESME) focused its resources on the problem, but it was soon obvious that the need far exceeded the resources available through traditional teacher education channels. Teacher education institutions are typically prepared to serve dozens of inservice teachers, or perhaps hundreds at best, each year through enrichment programs. However, thousands of teachers throughout the state were in need of immediate help.

Additional instructional resources were clearly needed to expand the capability of teacher education institutions for providing teacher enhancement programs. A search for options revealed only one source of an adequate number of potential instructional personnel with the interest, experience, and sensitivity to teachers' needs that would be required for the job: *Experienced Classroom Teachers.* Tapping that resource, however, required preparation of a corps of highly qualified teachers and principals capable of teaching their peers through local inservice education programs. The Collaborative Program Model (Figure 1) was designed for that purpose.

CONCEPTUALIZATION OF THE MODEL

The CEESME staff and the Tennessee State Department of Education's science consultant worked with local teachers and school administrators to develop a program that would help teachers prepare for hands-on-science instruction in all elementary grades. Six program criteria were established:

1. The program should provide intensive and extensive preparation in interdisciplinary science content and hands-on teaching methods.

2. Teachers should be prepared to work as teams to teach their new content knowledge and skills to other teachers through local and regional inservice programs.

3. Instruction in needs assessment and program development should be provided to enable teams to assess their local educational requirements and design projects tailored to those needs.

4. The principal of each team's school and the school system's supervisor of instruction should participate as co-equal team members with the teachers.

5. A field support system should be provided to assist the teams in implementing their projects.

6. Incentives such as scholarships and subsistence payments should be provided to encourage the participation of outstanding teachers.

Criteria 1-3 were developed by the CEESME staff and state science consultant, with input from a survey of local teachers' and school administrators' perceived needs for elementary science teaching. School officials were very supportive of the team concept as a means to encourage communication and enhance the sequence of science instruction across grade levels. Teachers and administrators alike believed that systematic involvement of teachers in local needs assessment and program planning would generate a sense of participation and ownership in educational reforms and result in better teacher morale in a time of change.

Criteria 4-6 were inspired by a review of literature on effectiveness of teacher enhancement programs. A study by Mechling and Oliver (1982), for example, indicated that the support and understanding of the building principal is critical to the success of any school science program. Many principals, however, have limited science backgrounds. While they may want to improve science instruction in their schools, principals often "wonder how and where to begin" (p. 4). When principals "had visions for the future of their schools, the teachers described those schools as good places for students and for teachers" (Rutherford, 1985, p. 32). On this basis, it was decided that principals should be centrally involved in the program.

Criterion 4 was established to enable principals to gain the science knowledge and instructional experience needed for a shared vision of excellence in science teaching. Clearly, science teaching has many things in common with other subject areas, but it has unique needs that are critical to effective education. Efficient implementation of reforms to meet those needs will require strong administrative understanding and support. Therefore, it was deemed equally important that each school system's supervisor of instruction participate in the program to insure support from that key administrative level. Principals and supervisors were expected to participate fully in all project activities, including science studies, planning and presenting hands-on science lessons for peer review, and conducting inservice programs and other field activities.

Subsequent planning indicated that a four-member team structure including a primary teacher (from grades K-3), an intermediate teacher (from grades 4-6), their principal, and the supervisor of instruction would be an appropriate size for a team. It was believed that this team structure would help to insure a balance of instructional and administrative insights in planning for reform and conducting inservice programs. To prepare the teams for their leadership roles, a Local Team Leadership Development (LTLD) component was added to the program agenda (Prather, Hartshorn & McCreight, 1988, p. 457).

Criterion 5 was based on a synthesis of evaluations of mathematics and science education programs by the U.S. General Accounting Office (U.S. GAO, 1984), which indicated that retraining of teachers alone was not sufficient for successful implementation of new school programs. Many inservice science teachers have been inspired by new ideas learned in summer institutes and other programs over the years, only to lapse into their previous practices upon returning to a school environment not conducive to change. An ongoing support system was needed, the U.S. GAO contended, to encourage teachers as they attempted the unsettling task of implementing new program concepts. On that basis, the project staff was expanded to include three full-time field supervisors to assist and encourage the teams in their field activities.

Criterion 6 was based on the U.S. GAO's (1984) conclusion that, "in the absence of substantial scholarship and subsistence payments, short and intensive programs seem to attract few students" (p. 56). To attract highly qualified participants of the type needed for leadership in educational reform, a per diem and a scholarship for 12 semester hours of graduate academic credit in science and professional development courses were offered for each participant. An honorarium of $2,000 per participant was also allocated for successful completion of all program activities.

IMPLEMENTATION OF THE MODEL

Proposals were submitted to the National Science Foundation and the Tennessee Higher Education Commission for a project to prepare 27 four-member teams over a three-year period. A three-phase program was proposed, with nine teams to be prepared in each phase of the project. Upon notification of funding, program announcements were circulated and team applications solicited. To distinguish the scope and focus of the program it was given the title "Elementary Science Education Institute (ESEI)" and the first phase of the program was implemented in January, 1987 (Prather, Hartshorn & McCreight, 1988).

Recruitment

Nine teams were recruited from geographically dispersed locations in West Tennessee for the first (1987-88) project phase, nine were recruited from Central Tennessee for the second (1988-89) phase, and nine were recruited from the Eastern part of the state for the final (1989-90) phase of the program. To recruit teams for each phase, the project staff circulated program information and team application forms to the Education Service Centers, rural elementary school principals, and superintendents of rural systems in the target areas. Also, the project director traveled throughout the target area to explain the program goals and team recruitment criteria to local and area meetings of elementary school teachers, principals, supervisors, and superintendents. Several principals invited the project director to visit their schools and explain the program to their teachers.

The superintendent of each rural school system was encouraged to submit a team application to include a principal and two inservice teachers with potential for leadership in elementary science reform, and the system supervisor of curriculum and instruction. When possible, the principal and teachers were to be from the same school. If a school did not cover all grades K-6, however, the second teacher could be recruited from another school in the system if her/his principal provided a written agreement to support the team's reform efforts. In the case of a team including the principal of a primary school, for example, the second teacher could be recruited from an intermediate school. Recommendation of the school superintendent was required for each team, along with written confirmation of the system's intention to support of the team's reform efforts.

Application forms called for information about each team member's academic preparation in science and experience in teaching elementary science. Final selection of teams was based on a combination of factors including science qualifications, with priority given to teams including members of minorities and other underrepresented groups in science, and geographic location. Attention to locations was important to provide a geographically dispersed network of teams across the state upon completion of the project. It was anticipated that these teams would provide on-going leadership for improvement of elementary science teaching through inservice education programs for their peers in surrounding school systems.

Applications for the first cycle were less than enthusiastic because of many applicants' uncertainty about the benefits of taking "another college science course like I took before." One applicant explained the nature of the concern: "Look," she said, "I certainly do not need more of the same! How do I know all this extra work will do me any good when I go to teach science to my kids?" Repeated reassurances that the courses would be taught in a non-traditional manner that should enable teachers to translate the science content they would study into lesson activities appropriate for elementary classroom use finally won out; the first cycle began with a full complement of nine, four-member teams. Once confident of the benefits of the program, several teams became strong promoters of the project at area and state meetings of teachers and principals. These program veterans were the project's best references, and the staff's job of recruitment was much easier for the second and third phases.

Applications were accepted only from complete, four-member teams. A provision was made for two teams to substitute a third teacher for the principal, with the understanding that the substitutes would serve as special science coordinators for their school systems. This arrangement was implemented on the recommendation of the project's external evaluators to provide a basis for comparisons of the effect of the principals' involvement in team activities. One system that did not have a full-time supervisor was allowed to substitute a teacher with supervisory credentials for the supervisor's position in its team, with the understanding that the teacher would be appointed as half-time science supervisor for the system for two years.

Academic Instruction

Approximately 240 hours of classroom instruction and supervised field activities were provided in four courses in each project phase (Prather & Hartshorn, 1989). Participants received 12 semester hours of graduate academic credit for successful completion of the courses. Two guiding principles prevailed throughout the program: (a) Teachers learn better when taught in the way they will be expected to teach, and (b) teachers like to learn from other teachers. In keeping with these principles, science faculty and other instructional personnel were required to employ "hands-on-science" methods to teach their lessons. Several exemplary elementary teachers with expertise in activities-oriented lesson planning and hands-on science teaching methods were employed to present model lessons, which enabled the participants to learn these methods from accomplished peers.

Hands-on teaching methods are characterized by the use of concrete manipulatives and activities-oriented instruction, as opposed to lectures and teacher-led discussions and demonstrations, to provide each participant an opportunity for first-hand experiences as a basis for developing an understanding of the concepts studied. Like the typical elementary classroom, the classrooms used for this project contained moveable tables and chairs rather than individual desks or theatre-style seating. A collection of elementary textbooks by various publishers was available for reference purposes, but no textbook was used for the courses. The instructors served as facilitators, or partners in learning with the participants, rather than subject-matter experts.

Model lessons using hands-on science teaching strategies were used to teach many complex science concepts such as Newtonian mechanics, structure of atoms, digestion, and the water cycle. Lessons modeling the use of discrepant events were also employed to demonstrate their effectiveness for generating an interest in learning. After experiencing lessons taught by the faculty and visiting elementary teachers with expertise in hands-on teaching methods, each team member was required to plan and conduct lessons using these methods to teach a scientific concept.

Instruction was spread over an intensive, month-long summer session and nine-hour weekend sessions during the academic year. Additionally, each team was required to plan a field practicum to be conducted over the subsequent school year. The academic component of the program, which was carefully attuned to applicable state and local curricular standards and the teams' professional development needs, included instruction in:

1. Physical, life, earth/space, and environmental science
2. Hands-on/minds-on science teaching methods
3. Safety in elementary science lessons
4. Planning elementary curriculum and instruction
5. Computers in science teaching
6. Career opportunities in science-related fields
7. Research and program evaluation
8. Career planning and leadership development
9. Principles of adult education
10. Inservice program planning and implementation
11. Public relations and dissemination of information

The physical sciences (physics, chemistry, astronomy, and geology) and life and environmental sciences were taught together rather than as traditionally separated disciplines. The science instruction was spread across all courses, along with other topics listed above. It was the consensus of the project planners that this approach would be more appropriate for providing the general science background needed for elementary science teaching. The decision was supported by input from teachers, curriculum supervisors, and the State Department of Education during project planning. The decision has been further supported by the fact that the National Science Teachers Association (NSTA, 1990a) and American Association for the Advancement of Science (AAAS, 1989; Rutherford & Ahlgren, 1990) have advocated an integrated science approach as more appropriate than discipline-specific instruction for all grades K-12.

Field Activities

Each team was required to assess local needs in elementary science curriculum and instruction and design a field project to help fulfill those needs. And Items 7-11 above were included to prepare the teams for that purpose. For the first six weeks of each phase, the participating teams were assigned specific tasks on a weekly basis leading to development of a long-range program for reform tailored to their particular school system. Each team selected its own approach to fulfilling those tasks.

The first assignment was for teachers and principals to survey their respective peers in their school system; the curriculum supervisor was asked to interview the central office personnel. Some teams developed questionnaires and conducted formal surveys of all teachers and administrators; others used a variety of methods including interviews and group meetings to collect information. At a subsequent class session, the teams reported the results to the total group and discussed key issues with science faculty, science educators, the state science consultant, and curriculum specialists. Some teams refined their list of needs to include important ideas that surfaced during the discussions. All teams identified systematic, inservice education on planning and conducting lessons using hands-on-science teaching methods to be a top priority for their systems.

The teams' second assignment was to review current research and trends in science education and identify options that may apply to their specific needs. The next week, the results were reported and the options listed for review by all teams. As before, several teams refined their list of options to include promising ideas identified by their peers. Following assignments included listing the resources needed to implement the chosen options, surveying local resources available for use, and identifying means for obtaining the remaining resources they would need.

Once the assessment of local needs was completed and acceptable options for meeting those needs were identified, the resultant project was assigned as that team's field practicum for the following school year. All teams were expected to schedule and conduct inservice programs for other teachers, beginning in their own school and branching out to other schools in their system and beyond. The teams were encouraged to prepare news releases and programs for presentation to community groups to inform the public of local science education needs and opportunities for reform.

Field Support System

Three exemplary elementary teachers were recruited from the target areas to serve as full-time field supervisors for the project. To insure continuity of retirement and other career benefits for these teachers, the university purchased their contracts from their respective school systems. The teachers were housed at strategically located education service centers throughout the area while working as field supervisors. They were provided support for travel. The teachers returned to their former classroom assignment at the conclusion of their service as field supervisor.

The field supervisors were selected on the bases of their science preparation, experience in teaching elementary science, and professional development. Requirements included Career Ladder Level III (the top category for classroom teachers), substantial academic preparation in science, and recommendation from her/his principal as having a demonstrated record of leadership in promoting science teaching in the elementary grades.

Throughout the instructional phases of the program, the field supervisors attended all classes and participated in all team activities to assure they were fully cognizant of the teams' special preparation and interests. They then monitored the teams' field activities, provided assistance in scheduling inservice programs in other school systems, served as liaison to state and local education agencies, and assisted the project director in program conduct and evaluation of project effect. Also, they assisted teams with presentation of programs at state, regional, and national meetings of teachers, including the National Science Teachers Association.

ASSESSMENT OF THE EFFECTIVENESS OF THE MODEL

A total of 108 participants (27 four-member teams) were involved in the program, including 57 teachers, 25 principals, and 26 supervisors. More than 1,100 elementary students were directly involved in classes taught by the teachers. Project effect was assessed on the basis of science performance and attitudes of the participants, teachers' use of hands-on science teaching methods, performance of students taught by participating teachers, the scope of the teams' inservice education activities, and involvement of principals.

Performance and Attitudes of Participants

Data on the teachers' and administrators' science content knowledge were gathered for each program phase through pretests at the beginning of instruction and posttests upon completion of the coursework. An 80-item survey instrument was developed and its reliability and validity established (Prather & Hartshorn, 1989). Pre- and post-instructional attitudes of participants toward science and science teaching were assessed, also, using a 70-item attitude survey instrument developed for the purpose.

Significant gains ($p < .01$) in science performance were observed among both teachers and administrators. The total group showed an overall gain of approximately ten percent (10%) in science content mastery. Gains in specific areas ranged from approximately eight percent (8%) in environmental science, nine percent (9%) in life science, nine percent (9%) in physical science, and sixteen percent (16%) in earth and space science.

Favorable changes in attitudes toward science and science teaching were also observed among both teachers and administrators, but problems with data collection did not allow determination of whether the differences were significant. However, certain data revealed strong evidence of increased self-confidence. At the beginning of their academic preparation, for example, only about 26 percent of the teachers and administrators indicated confidence that they could teach hands-on science lessons as required by the state science curriculum. After completing the project, 100 percent agreed or strongly agreed that they could do an effective job of hands-on science teaching (Prather & Hartshorn, 1989). Approximately 60 percent of the participants added at least one additional affiliation to a professional association related to science education.

Use of Hands-on Science Teaching Methods

Examination of teachers' use of hands-on science teaching strategies was accomplished using videotape-jury review techniques. Portable videotaping units were provided to each team for the duration of the project. Each teacher was required to videotape one school science lesson prior to the beginning of their academic preparation and three during the subsequent school year. The first videotaped lesson provided base-line data for comparisons of usage of hands-on teaching methods after completion of the coursework. The videotapes were submitted to three external teacher evaluators, selected for their expertise in hands-on science teaching methods, for analysis using videotape lesson assessment forms developed for the study (Prather, Hartshorn & Walters, 1990).

The evaluators identified and described hands-on science events (lesson activities that actively involved students in the use of concrete manipulatives) that engaged the students in experience-based learning about science during each lesson. An overall increase of approximately 50 percent in the number of hands-on science activities scheduled by teachers in science lessons was observed over the test period. Approximately 80% of the teachers showed an increase in the use of hands-on science activities (Prather, Hartshorn & Walters, 1990). Most of the remaining 20 percent of the teachers demonstrated consistent usage of hands-on teaching strategies from the beginning. The project staff speculated that these teachers were among the 26 percent of participants that had indicated early confidence in their hands-on teaching skills.

Performance of Students Taught by the Teachers

Pretests and posttests were used to collect data for comparisons of science achievement among students taught by the participating teachers compared with that of students in the same grades taught by non-participating teachers in the same school (HOME) and in schools in non-participating school districts (CONTROL). Separate instruments for grades K-3 and grades 4-6 were developed based on the state science curriculum standards. (Hartshorn & Nelson, 1991).

Comparisons of performance of students taught by the 57 participating teachers with that of control groups were based on data from 130 elementary classrooms involving more than 3,000 students across the state. Analyses of the data indicated consistently and significantly higher performance ($p < .01$) among primary (grades K-3) students taught by the project teachers compared to the HOME and CONTROL groups. Significant gains ($p < .05$) were also observed among intermediate students (grades 4-6) taught by project teachers compared to both comparison groups, with the exception of non-significant gains compared with CONTROL in the fourth grade. Hartshorn and Nelson (1991) examined project effects on participating teachers and their students in more detail.

Inservice Activities

Information on the teams' performance as providers of inservice education was particularly germane to the validation of the Collaborative Program Model. Each team was required to conduct three inservice programs as part of its field practicum. A total of 81 inservice programs was expected to be presented by the 27 teams. By the end of the first project phase, the initial nine teams alone had exceeded that goal with 117 inservice programs involving more than 2,000 elementary teachers. Two teams had presented workshops for out-of-state groups. The remaining teams were similarly productive. By the end of the third project phase, the 27 teams had planned and conducted more than 330 programs directly serving more than 7,800 teachers, principals, and other educators. There was much variation in team activity, but approximately 93 percent (25 teams) completely fulfilled the required inservice leadership activity for their school systems and approximately 70 percent (19 teams) far exceeded the anticipated level of service.

Involvement of Principals

Early in the program, the value of the participation of principals in the program had been questioned by some project participants. One teacher's comment reflected the general nature of the concern: "Principals work mostly in administration, not teaching. Involving more teachers would be better, since they would know what's needed in the classroom." However, a survey of teaching experience among the participants revealed that the average years of classroom teaching experience among the principals was within a few years of that of teachers. That information helped to alleviate the concern and bridge the gap between teachers and administrators; close, collegial working relationships among team members soon prevailed.

Generally, the principals and supervisors assumed their role as team members with enthusiasm. The team that logged the greatest number of inservices (35 in all) attributed their outreach to the enthusiasm of their principal. One teacher on that team reported on the principal: "He never lets us set up a workshop without being sure we invite the principals. He will tell you plainly that they ought to be involved, and he always does part of the teaching." That principal also strongly encouraged principals on other teams to take the initiative in getting invitations for their teams to conduct workshops in other school systems. "This helps to establish our own schools and teachers as leaders working for better science," he declared, "and we need that kind of recognition." Inservice workshop evaluations revealed that prominent involvement of principals in inservices was viewed as unusual and commendable by the majority of teachers attending the programs.

Among the three teams that substituted another teacher for the administrator, inservice activities and other leadership functions were substantially more limited than with the other teams. Only two of these teams ventured beyond the confines of their own school building to conduct inservices or other leadership activities. In one of the two cases, most of the field activities were conducted by one or both of the team's teachers with assistance from a field supervisor.

More than half of the teams remained active two years after completion of the project. Teams or team members were frequent contributors at statewide, regional, and national meetings of the National Science Teachers Association and similar groups. Several teams made presentations for school systems in other states including Kentucky, Missouri, and Ohio. This indicated the project's success in developing local resources for on-going leadership in the reform of elementary science education.

BENEFITS TO THE PARTICIPATING SCHOOLS

Participating school systems gained a highly qualified team of educators with insight into both the instructional and administrative implications of educational planning and development. This insight, and the teams' training in needs assessment and inservice education, contributed to clear channels of communication that should benefit those systems in efforts for improvement in other subject areas.

Equally important, the teachers gained new science teaching skills for use in their own classrooms and promptly set about spreading their new knowledge to their peers throughout the school system. Increased awareness of the nature and applications of hands-on science teaching methods was generated by team presentations at area and state meetings of elementary teachers and principals, and the teams were quickly recognized as highly credible and uniquely prepared resources for inservice education programs. As indicated earlier, the number of inservice programs conducted by the teams far exceeded the project expectations; and, as recognition of their work extended beyond state lines, members of several teams accepted invitations to provide inservice programs in Kentucky, Missouri, and Ohio.

The teams' experience in using news releases and special programs for public information purposes also benefited some school systems in their efforts to raise local support for school projects such as elementary science laboratories. For example, most teams were quick to see the usefulness of the portable videotaping units to produce videotapes of students studying hands-on science for use in presentations to local civic and social groups and other public information purposes. It is anticipated that the resultant increased public awareness of the purposes and potential of science education will rank among the greatest long-range benefits of the project. Additionally, many of the school systems gained statewide and regional recognition for leadership and service through programs presented by the teams, which enabled the teams to have a greater voice in overall planning and policy-making.

Perhaps most important of all, the participating school systems found within their own ranks the talent and inservice training capabilities necessary to prepare to meet the mandate for a new instructional approach to elementary science education. The teams' responses to requests for inservice programs for teachers in other schools inspired further confidence that the teaching profession can marshall the resources for effective reforms. This sort of self-confidence and sense of contribution constitutes an example of teacher empowerment in the truest meaning of the term, and the widespread effect of the project on the teachers' self-confidence was reflected by the decision of 56 of the participants to list themselves as consultants in the *Tennessee Directory of Resource Persons for Inservice Science Programs* (Nelson, 1990).

A deep sense of contribution was expressed in the following words of a first-phase participant as she explained the enthusiastic reception her team had received for its initial inservice programs to the new teams at the beginning of the second phase:

> Just a year ago I was very discouraged; but I feel very, very good about being a science teacher now. And that makes my whole life and all the years of school and all the work in my classroom seem more than worthwhile. What we do is important, and folks realize that!

Reflecting on the process of reform in education, Shymansky and Kyle (1992, p. 759) concluded that "change in schools requires leadership, staff development, changes in the organizational structure, and the involvement of people from all aspects of the educational system." Throughout the process, they added, "teachers will need to construct collegial ties within and beyond the school, as well as assume leadership roles associated with the process of reform and professional renewal." This will require self confidence, commitment, and cooperation of teachers and administrators in a collegial effort to effect change. The Collaborative Program Model was designed to unite schools and universities in an effort to prepare teams of teachers and administrators to assume that leadership role, beginning in their local schools and spreading outward through a grass-roots program of program assessment and reform.

RECOMMENDATIONS FOR REPLICATION

The Collaborative Program Model was adopted with success for a local team leadership development program conducted by East Tennessee State University (Rhoton, Cantwell, Messimer & Christian, 1991). The local team leadership promoted by the model has been cited as an effective alternative to the elementary science specialist for schools in rural and small systems, where the support of a specialist's position may not be economically feasible (Rhoton, Field & Prather, 1992). On that basis, institutions serving rural and small school systems are encouraged to examine options for employing the model to incorporate leadership preparation into inservice science teacher enhancement programs.

The model's emphasis on integrated curriculum and hands-on/minds-on science teaching methods is very compatible with the constructivist perspective of science learning (Saunders, 1992). These emphases are also compatible with reforms advocated by the American Association for the Advancement of Sciences Project 2061 (AAAS, 1989) and National Science Teachers Association (NSTA, 1990a). Reflecting on those reform efforts, Shymansky and Kyle (1992) concurred that "the rigid boundaries between the disciplines must begin to crumble so that students can experience the connections between the disciplines" (p. 764). Hewson and Hewson (1988) noted in a review of studies on science learning that "a large body of research in recent years has produced a general picture of science learning and this picture is a constructivist one" (p. 597). A balanced emphasis on the constructivist perspective of science learning, the hands-on science approach to teaching, and an integrated science content should be central to the replication of the Collaborative Program Model.

The model is neither content-specific nor grade-level sensitive; however, it may be adapted to any subject area. For projects related to secondary language studies, for instance, the teams may include a high school English teacher, a teacher of a foreign language, their principal, and a supervisor of instruction. Institutions interested in implementing the model are encouraged to place strong emphasis on the following recommendations:

1. Teachers and administrators representing the school systems to be served should be centrally involved in the planning of the project.

2. Involvement of the building principal as a full member of the team should be a requirement for a team's participation in the program.

3. In the event the local school structure precludes both teachers being from the same school (i.e., a primary school may cover grades K-3 only, with a separate school for grades 4-6), the principal from one of the two schools should participate. The principal of the second school should

provide written evidence of support of the team's field activities and inservice education programs.

4. Instructional personnel should be required to use the type of teaching methods that the participating teachers will be expected to use in their classrooms.

5. The subject matter should be presented in a manner that can be readily translated into lesson activities for use in the grade levels the participating teachers will teach.

6. Each team should be required to prepare and present a minimum number of five inservice programs. At least two should be presented to teachers' groups outside the team's school system.

7. Teams should be given the instruction needed to prepare them to conduct a local needs-assessments and plan programs to help meet those needs in a timely manner.

8. Instruction on the principles of adult education and inservice program planning should be provided to prepare the teams for ongoing local leadership through inservice education.

9. At least one field supervisor, preferably an exemplary teacher in the subject area and grade levels covered by the project, should be employed full time to provide a support system for the teams' field activities.

10. Participant benefits such as an honorarium, *per diem*, and scholarship for academic credit should be provided to encourage participation.

ACKNOWLEDGMENTS

The elementary science education project discussed in this article was supported in part by grants from the National Science Foundation (TEI-8651464) and the Tennessee Higher Education Commission. The opinions, findings, and conclusions or recommendations expressed in this article are those of the author and do not necessarily reflect the views of the National Science Foundation, Tennessee Higher Education Commission, or University of Tennessee at Martin Center of Excellence for Science and Mathematics Education.

Special recognition is accorded Dr. Maurice H. Field, Professor and Director of the Center for Environmental and Conservation Education at the University of Tennessee at Martin (UTM), and Dr. Robert L. Hartshorn, Associate Professor and Associate Director of the UTM Center for Science and Mathematics Education, for their contributions to the elementary science education project. Dr. Field was primary architect of the program that produced the Collaborative Program Model and Dr. Hartshorn designed the assessment instruments and supervised the research agenda.

REFERENCES

American Association for the Advancement of Science. (1989). *Project 2061: Science for all Americans.* Washington, DC: Author.

American Council on Education & Education Commission of the States. (1988). *One-Third of a Nation.* Washington, DC: Authors.

Field, M. (1988). A chronicle of changes for elementary science in Tennessee. *Education, 108,* 419-426.

Gabel, D., Samuel, K., Helgenson, S., McGuire, S., Novak, J., & Butzow, J. (1987). Science education interest of elementary teachers. *Journal of Research in Science Teaching, 24,* 659-677.

Hartshorn, R., & Nelson, R. (1991, March). *Three-year elementary science leadership development program: Analysis of the effects on the participants and their students.* Paper presented at the 1991 National Convention of the National Science Teachers Association, Houston, TX.

Hewson, P., & Hewson, M. (1988). An appropriate conception of teaching science: A view from studies of science learning. *Science Education, 72,* 597-614.

Holmes Group. (1986). *Tomorrow's teachers.* East Lansing: The Michigan State University.

Mechling, K., & Oliver, S. (1982). *Handbook 1: The principal's role in elementary school science.* Washington, DC: National Science Teachers Association.

National Commission on Excellence in Education. (1983). *A nation at risk.* Washington, DC: U.S. Department of Education.

National Science Teachers Association. (1983). Recommended standards for the preparation and certification of teachers of science at the elementary and middle/junior high school levels. *Science and Children, 21*(1), 65-70.

National Science Teachers Association. (1990a, April/May). Science teachers speak out: The NSTA lead paper on science and technology education for the 21st Century. *NSTA Reports,* 42-44.

National Science Teachers Association. (1990b, May). *Scope, Sequence, and Coordination of Secondary Science: A Rationale (SS&C).* (Available from the National Science Teachers Association, 1742 Connecticut Avenue NW, Washington, DC 20009.)

Nelson, R. (1990). *Tennessee directory of resource persons for inservice programs.* Martin: University of Tennessee at Martin Center of Excellence for Science and Mathematics Education.

Pederson, J. E., & McCurdy, D. W. (1992). The effects of hands-on, minds-on teaching experiences on attitudes of preservice elementary teachers. *Science Education, 76*, 141-146.

Prather, J. P., & Hartshorn, R. (1989). Evaluation of a model for reform of elementary science instruction in rural and small school systems. *Journal of Rural and Small Schools, 3*(3), 6-13.

Prather, J. P., Hartshorn, R., & McCreight, D. (1988). A team leadership program: The elementary science education institute (ESEI). *Education, 108*, 454-462.

Prather, J. P., Hartshorn, R., & Walters, N. (1990). A survey instrument for qualitative and quantitative examination of hands-on-science instruction using videotape-jury review techniques. *Journal of Elementary Science Education, 2*(1), 16-29.

Rutherford, W. (1985). School principals as effective leaders. *Phi Delta Kappan, 67*(1), 31-34.

Rutherford, F. J., & Ahlgren, A. (1990). *Science for All Americans.* New York: Oxford University Press.

Rhoton, J., Cantwell, D., Messimer, W., & Christian, J. (1991, March). *Teaching elementary school science: A model for improving teacher education.* Paper presented at the 1991 National Convention of the National Science Teachers Association, Houston, TX.

Rhoton, J., Field, M. H., & Prather, J. P. (1992). An alternative to the elementary science specialist. *Journal of Elementary Science Education, 4*(1), 14-25.

Saunders, W. L. (1992). The constructivist perspective: Implications and teaching strategies for science. *School Science and Mathematics, 92*, 136-141.

Shrigley, R. (1974). The attitude of preservice elementary teachers toward science. *School Science and Mathematics, 74*, 243-246.

Shymansky, J., & Kyle, W. (1992). Overview: Science curriculum reform. *Journal of Research in Science Teaching, 29*, 745-778.

Shymansky, J., Kyle, W., & Alport, J. (1983). The effects of the new science curricula on student performance. *Journal of Research in Science Teaching, 20*, 397-404.

U.S. Department of Energy. (1990, May). *Math/science education action conference report.* Washington, DC: National Technical Information Service, U.S. Department of Commerce.

U.S. General Accounting Office. (1984). *New directions for federal programs to aid mathematics and science teaching.* Washington, DC: U.S. Government General Accounting Office.

Weiss, I. (1978). *Report of the 1977 national survey of science, mathematics, and social studies education.* Washington, DC: U. S. Government Printing Office.

Weiss, I. (1987). *Report of the 1985-86 national survey of science and mathematics education.* Research Triangle Park, NC: Research Triangle Institute.

Wise, K. C., & Okey, J. R. (1983). A meta-analysis of the effects of various science teaching strategies on achievement. *Journal of Research in Science Teaching, 20,* 419-435.

Chapter 9

Texas' Science Inservice Programs for Elementary Teachers: *Stepping* and TESIP

Melanie C. Lewis
James P. Barufaldi

For the past 30 years, a hands-on approach to science instruction has been the focus of elementary science instruction. Although this approach has been shown to be effective in producing desired outcomes (Shymansky, et al., 1982), typically, elementary science has been taught by reading about science rather than doing science (Mechling and Oliver, 1983). To facilitate change in elementary science instruction, opportunities for elementary teachers to develop new beliefs, knowledge, and skills should be provided (Bybee, 1988). The elementary inservice programs developed in Texas with Title II funding from the Texas Education Agency, *Stepping* into Successful Science Teaching (*Stepping*) and the Texas Elementary Science Inservice Program (TESIP), offer these opportunities. *Stepping* and TESIP are providing Texas elementary school teachers with the knowledge and teaching strategies for effective science instruction.

PART I: *STEPPING* INTO SUCCESSFUL SCIENCE TEACHING

Background

In the early 1980s, national concerns were raised about the need for a scientifically literate citizenry (National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983). Among the recommendations for meeting these concerns at the elementary school grade levels were to provide a curriculum that emphasizes gathering and processing data and to offer teacher training in methods for teaching science in the elementary school (National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983).

In 1983-84, the *Texas Essential Elements* for course instruction in the Texas elementary and secondary schools were established by the state legislature. The Essential Elements are the rules for curriculum for public schools in the state of Texas. Teachers are required to provide instruction in the Essential Elements, which, for Grades 1-6, consist of the inquiry process skills of science, adapted from those in the *Science—A Process Approach* program (AAAS, 1970). At the present time, both the basic process skills and integrated process skills are required instruction for Grades 1-6. Very little science content is specified in the Texas Essential Elements for these grade levels, although a content focus for grade levels (for example, life science content at grade levels one and four) is recommended. In 1986, funding was provided by the Texas Education Agency to develop and disseminate an elementary science inservice program for training teachers to use the Essential Elements in their classrooms. *Stepping* Into Successful Science Teaching is the result of that funding.

Consistent with national recommendations (National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983), *Stepping* provides elementary teachers with knowledge of data-gathering and data-processing techniques, shows how science is relevant to students, and provides strategies for implementing these in their classrooms. "*Stepping* into Successful Science Teaching" was developed under the auspices of the Edwards Aquifer Research and Data Center, Southwest Texas State University (SWTSU), San Marcos, Texas, Dr. Glenn Longley, Project Director. Dr. Melanie Lewis and Dr. Karen Ostlund developed the projects' written instructional materials. Dr. Paul Raffeld, Director of the SWTSU Testing Center, prepared the statistics and evaluation. Funding for the project was provided by Public Law 98-377, Education for Economic Security Act, Title II, through the Science Section, Division of Curriculum Development, Project #5669030, Texas Education Agency, Austin, Texas.

Description of Program Materials

Rationale and Objectives

In keeping with the Texas Essential Elements for science, the *Stepping* program was designed to give teachers knowledge of and hands-on experience using the inquiry process skills. The basis for the selection of the topics for the lessons in the *Stepping* program was an examination of methods a person needs to know in order to teach the inquiry process skills. The methods selected include research-based strategies such as cooperative-group techniques and questioning skills. A lesson plan format suggested by Cain and Evans (1984) provides an instructional strategy that encourages students' use of process skills by including data-gathering and data-processing components. The lesson plan format also allows the use of discrepant events as a motivating technique. Exemplary instructional materials, such as those developed at the Lawrence Hall of Science, Berkeley (SAVI/SELPH, 1981), were included as examples of appropriate, high-quality curriculum materials available for teachers' use. The program also recognizes science textbooks as an important curriculum material and shows teachers how these can be used to teach a hands-on science program.

Components

Stepping consists of six lessons, six videotapes to accompany each lesson, and an "Instruction Manual" (Lewis and Ostlund, 1986). The "Instruction Manual" contains two sections: (a) a Leader's Guide which contains information and transparency masters for the inservice facilitator, and (b) a section of Instructional Materials that contains master copies of handouts for participant teachers.

The six lessons in the *Stepping* program carefully develop teachers' understanding and use of the science process skills through modeling, discussing, and doing science investigations. Each lesson begins with a videotape presentation followed by discussions and hands-on activities generated by the videotapes. The lessons are developed using the same planning, grouping, and questioning strategies suggested by the program.

Lesson #1: Introducing Essential Elements/Inquiry Process Skills.

Objective: to define and use the basic process skills and higher level (integrated) process skills to investigate phenomena.

Lesson #1 provides definitions, examples and activities to demonstrate the basic and integrated process skills as stated in the *Texas Essential Elements* and *Science—A Process Approach* (AAAS, 1970). The lesson is introduced by a videotape interview of four scientists who describe their work. Discussion develops the idea that the process skills are what scientists do in their work. Then, activities representative of the basic and integrated science process skills (Essential Elements) complete the lesson (refer to Table 1.)

Lesson #2: Managing the Science Classroom.

Objective: to set up cooperative task groups to distribute, use, and collect manipulative science materials in a hands-on science lesson.

An activity approach to science instruction requires a classroom that organizes people and materials efficiently and effectively. Cooperative task groups have been shown to be an effective strategy for doing this while promoting learning and positive attitudes (Johnson, 1984). The management system used in this lesson was suggested by Jones (1985). This system designates each student's function within the group. The "principal investigator" is in charge of carrying out the task; the "materials manager" obtains and distributes the materials and equipment; the "recorder/reporter" gathers and records information and reports results to the class; and the "maintenance director" administers the clean up of the work station. This management system provides an efficient way to get and distribute equipment and materials, promotes student responsibility, and advances safety in the classroom by reducing the number of students moving around.

The videotape shows a class divided into cooperative groups doing a hands-on science lesson. After discussion of the videotape, participants do several

Table 1. Process Skills (Essential Elements) and Related Activities

Process skill (Essential Element)	Activity
Observing	Observe and record observations of a candle before, during, and after it has burned
Classifying	Classify buttons based on their common properties
Communicating	Give and receive directions for constructing tangram figures
Measuring	Measure heights, spans, and other lengths using metric measuring tapes
Inferring	Infer what is inside a closed box based on the sounds made by the objects in the box
Predicting	Predict how many M & M's™ are in a bag and the number of each color
Relating objects and events to other objects and events	Relate the length of drinking straw flutes to the pitch of the sound and to musical instruments
Defining operationally	Write operational definitions for the variable "amount of plant growth"
Investigating	Design and carry out an investigation to determine the relationship between the length of a rubber band and the number of weights added to it

activities in cooperative groups. Discussion of competitive, individualistic, and cooperative tasks concludes the lesson.

Lesson #3: Planning Effective Science Lessons.

Objective: to select a science topic and design an instructional strategy that includes Essential Elements, behavioral objectives, materials, effective teaching techniques (motivation/introduction, data-gathering, data-processing, and closure), and methods of evaluation.

This lesson introduces a strategy for planning an effective, hands-on science lesson. The strategy includes these components: motivation/introduction, data-gathering, data-processing, evaluation, and closure. The components of this strategy are compatible with the Texas Teacher Appraisal System (the teacher evaluation system used in Texas). The videotape shows a lesson being taught that uses the components of this instructional strategy. After viewing the videotape, teacher participants are given more information about each of the lesson's components, and the components are discussed. Finally, teachers plan their own lesson using the strategy.

Lesson #4: Using Questions for Teaching Science.

Objective: to identify and categorize questions that promote recall, data-gathering, data-processing, and evaluating skills.

This lesson was developed to provide a simple question category system that would focus teachers' attention on the inquiry process skills. The category system devised was based on systems described by George, Dietz, Abraham & Nelson (1974) and Rowe (1978). For simplicity, only four categories were used, and category titles were selected that relate to titles used in other *Stepping* lessons. The four categories of teacher questions and student responses are recall, data-gathering, data-processing, and evaluating. Table 2 describes and gives sample

Table 2. Categories of Teacher Questions and Student Responses

Category	Description	Sample Question
Recall	Requires remembering information	"How many of you have been to the beach?"
Data-gathering	Requires observing to get information	"What do you observe about the color of your rock?"
Data-processing	Requires putting observations together	"What could be in the box that would have that sound?"
Evaluating	Requires making judgements from information	"Which of these objects—a match, a radio, or a container of water—would be most useful on the moon?"

questions for each category.

This lesson begins with a videotape of a model teacher asking questions about a science lesson. Some of the questions asked by that teacher are identified as belonging to a question category. After discussing the tape and the question categories, participants observe the behavior of raisins in soda pop, and practice being the respondent to questions. Then, they categorize the questions asked them. Participants practice using the category system by categorizing textbook questions. The lesson concludes with participants writing their own questions for an activity selected from their science textbooks.

Lesson #5: Providing for Individual Needs.

Objective: to examine adaptations in science teaching for students having different needs and become familiar with materials and resources available for teaching science to students with physical, social, and intellectual differences.

Teachers encounter and teach students with a wide variety of skills, abilities, and needs. This lesson is based on the idea that a hands-on, multisensory approach to science instruction is good for all students. This approach is exemplified by the Lawrence Hall of Science program *Science Activities for the Visually Impaired/Science Enrichment for Learners with Physical Handicaps* (SAVI/SELPH, 1981).

The videotape of this lesson shows classes of gifted students and special needs students doing SAVI/SELPH activities. After discussing the video, participants then do several SAVI/SELPH activities. The SAVI/SELPH philosophy is discussed, and materials and equipment from that program are displayed.

Lesson #6: Making Science Relevant.

Objective: to observe how science is an integral part of everyday life.

For science to be of importance to students, it must be made relevant to their everyday lives. Science and technology can be observed in the home and the everyday life of children, and science process skills can be used to give information needed to make decisions encountered in everyday life.

The videotape of this lesson shows a child doing at home activities. Teachers write a script for the video by relating the child's activities to science and science investigations. Consumer decisions are made in an activity using science process skills to identify the best buy among several paper towels. Finally, science is related to other school subjects in an activity involving writing a poem about water.

Training Workshops

The goal for dissemination of the program was to train facilitators who would, in turn, train teachers. In August and September 1986, the first two workshops were given primarily to classroom teachers. Eight more two-day training workshops were held across the state from 1986 to 1987 that were designed to train facilitators who would in turn train classroom teachers.

The "Instruction Manual" was designed for workshop facilitators and contains detailed instructions for presentations. These include the sequence of presentation for each lesson; a way to introduce and close lessons; a brief description of each activity with approximate time required for presentation; a way to introduce, instruct, and close activities; questions to ask in discussions of the videotapes and activities; and materials needed, transparency masters, handout masters, and advanced preparations required.

Facilitator training workshops modeled the instructions provided in the manual. Lessons 1-3 were covered on the first day of training, and Lessons 4-6 on the second day. Tables 3 and 4 show the agenda for a two-day training workshop for facilitators. Workshops for teachers require a longer presentation time of about three to four days. All six lessons in the *Stepping* program are independent and can be presented separately. However, experience has shown that since the entire program is designed to encourage the use of process skills,

Table 3. Agenda for a two-day facilitator training workshop—Day 1

Time	Activitity
8:00 - 9:00 a.m.	Welcome, Pretest, Break
9:00 - 9:45	LESSON 1: View and discuss videotape
9:45 - Noon	Activities 1.1-1.8 Basic and Integrated Process Skill Activities
Noon - 1 p.m.	LUNCH
1:00 - 1:45	Activity 1.9 Integrated Process Skill Activity
1:45 - 2:10	LESSON 2: View and discuss videotape
2:10 - 2:45	Activity 2-1 What's in a bag of M & M's™
2:45 - 3:00	BREAK
3:00 - 3:50	Activity 2-2 Goal Structures
3:50 - 4:15	LESSON 3: View and discuss videotape
4:15 - 5:00	Discuss Activity 3-1 Planning effective science lessons

Table 4. Agenda for a two-day facilitator training workshop—Day 2

Time	Activity
8:00 - 9:00 a.m..	LESSON 4: Introduction; View and discuss videotape
9:00 - 9:45	Activity 4-1 Categorizing Teacher Questions
9:45 - 10:00	BREAK
10:00 - 10:35	Activity 4-2 Categorizing Textbook Questions
10:35 - 11:15	LESSON 5: View and discuss videotape; history and philosophy of SAVI/SELPH
11:15 - Noon	Activity 5-1 "Swingers"
Noon - 1:00 p.m.	LUNCH
1:00 - 1:30	Activity 5-2 "Dropping-In"
1:30 - 1:50	Discussion of SAVI/SELPH printed materials and equipment kits
1:50 - 2:20	LESSON 6: View and discuss videotape
2:20 - 3:00	Activity 6-1 "Write a script"
3:00 - 3:15	BREAK
3:15 - 4:00	Activity 6-2 "The Paper Caper"
4:00 - 4:30	Activity 6-3 "Liquid Poetry"
4:30 - 5:00	Posttest

it is advantageous to introduce these with Lesson 1.

Instruction for each lesson follows the same pattern—introduction, view and discuss the videotape, activities, and closure. The introductions are used to involve and interest participants in the lesson. The videotapes for most of the lessons (Lessons 2, 3, 4, and 5) serve as models of instruction, for example, the videotape of Lesson 2 shows a class organized and functioning in cooperative groups. After discussing the skills and ideas presented in the videotape, participants then complete one or more activities. The closure is a summary of what was learned in each lesson.

Of the approximately 210 total trainees, 171 were facilitators, each obligated to train at least 20 teachers. Facilitators included Education Service Center (ESC) personnel, representatives of teacher centers from the 67 colleges and universities in Texas, science supervisors from Texas school districts, lead teachers, and elementary school principals. Videotapes and instructional guides, for facilitators and the classroom teachers they were to train, were supplied to all facilitators.

In addition to training workshops, dissemination efforts have included presentations at state, regional, and national science teachers' conferences. Both *Stepping* and TESIP were presented in a minicourse at the 1992 National Science Teachers' Association (NSTA) conference. During 1991-1992, the Texas Education Agency funded ESC training in *Stepping* in conjunction with TESIP training (refer below to TESIP, Training Workshops). The *Stepping* materials are currently available at the 20 ESCs in Texas, the Texas Education Agency, and the Edwards Aquifer Research and Data Center.

Evaluation

Several aspects of the *Stepping* program were evaluated, including quality of the materials, assessment of participant achievement of workshop content, assessment of participant confidence regarding their understanding of science instruction methods, and an assessment of the value of the workshop. During the development phase of the program, the quality of the materials was assessed by on-going meetings of an advisory board, consisting of science educators, public and private school representatives, teachers, and media experts. Assessments also were made to determine content achievement, confidence, and value of the workshop to the participants, using evaluation instruments that were co-written by the program developers and the director of the university's testing center.

Pre- to post-evaluation data are available for 133 facilitator participants and 39 classroom teachers. The assessment of workshop content achievement was accomplished using a 16-item objective test. Questions were multiple-choice items assessing knowledge and applications of science process skills. The gain for the 39 classroom teachers was considerably greater than that found for the 133 facilitators. For the 39 classroom teachers, the pretest mean score was 8.8 out of 16 questions or about 55% correct. The posttest mean score was 12.6 out of 16 questions or 79% correct. The t value of 8.69 ($df = 38$) was significant beyond the .001 level. The average gain of about 4 raw score points represents a 43% increase from pretest to posttest mean.

For the 133 facilitators, the pretest mean was 11.5 (73%) correct, and the posttest mean, 13.7 (87%) correct. The t value of 9.2 ($df = 132$) was statistically significant beyond the .001 level. The average gain of about 2 raw score points represents a 19% increase. The results for facilitators are considered of less practical significance than those found for classroom teachers, because facilitators included many professional science educators.

The assessment of participant confidence was obtained using a 20 item questionnaire administered before and after each workshop. Confidence was indicated on a 5 point scale (A-E) representing least confidence (A), moderate confidence (C), and most confidence (E). Sample questions include "Being able to plan learning activities for children which emphasize the development of inquiry/process skills," and "Being able to identify and distinguish among essential elements involved in teaching-learning activities." Frequencies and percents were obtained for each of the 20 items. Results indicated that on the average about 19% of the 39 classroom teachers picked the higher confidence ratings of D and E on the pretest, while 47% picked the D and E ratings on the posttest. Items D and E were picked by 13% of the facilitators on the pretest and 44% on the posttest. A statistical analysis of the confidence data was conducted by summing across the 20 questions on the questionnaire. The lowest summed rating was 20, the highest, 100.

Statistically significant gains were seen for both groups—(38) = 6.43 for the classroom teachers and *t*(132) = 13.67 for the facilitators, both significant beyond the .001 level. These data support the effectiveness of the workshops in promoting high confidence among both classroom teachers and facilitators who will present the workshops to others.

Six specific questions were used to assess the value of the workshop to the participants. The questions included an assessment of relevance of the workshop and the effectiveness of the workshop presentation. Over three fourths of the classroom teachers and facilitators indicated in responding that the workshop was relevant and the presentations were effective.

PART II: THE TEXAS ELEMENTARY SCIENCE INSERVICE PROGRAM

Background

The 1980s were especially difficult for teachers, science educators, pupils, and parents who strongly supported the inclusion of science in the elementary curriculum and believed that it is a necessary and beneficial component in the schools. Numerous studies have documented that less science is taught in elementary schools than any other subject. The quality of instruction has also been questioned and many have noted that the delivery system for elementary school science does not reflect the essence of contemporary school science (Gumnick, 1985; Mullins & Jenkins, 1988; Tyson-Bernstein, 1988).

This deficit in science teaching appears to be the consequence of many concerns that elementary teachers have about teaching science, such as the lack of materials and appropriate training, questionable support from administrators, and the feeling of insecurity and incompetence (Barufaldi, 1987; Barufaldi, 1989; Carnegie Forum on Education and the Economy 1986; National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, 1983; Powledge, 1989).

Quality instruction in elementary school science is the focus of the Texas Education Agency (TEA). TEA recognizes that the teacher is of central importance in communicating the "essence of science" to children. The thrust of the Texas Elementary Science Inservice Program (TESIP) is to present an exemplary inservice program to help teachers communicate science to children that will enable these young learners to become scientifically literate today and beyond.

Description of Program Materials

The Texas Elementary Science Inservice Program (TESIP) is a cooperative professional endeavor of the Science Education Center, College of Education at The University of Texas at Austin and the Texas Project 2061, San Antonio, Texas (Barufaldi, Carnahan, & Rakow, 1991), developed for the Texas Education Agency, Title II, Project #00690401-04, 1990-91. TESIP was designed in response to the crises in science education and more specifically to reflect the spirit and the implications of the *Proclamation of the State Board of Education Advertising for Bids on Textbooks—No. 66* (TEA, 1991). An advisory board of science educators, master teachers, and scientists was organized to direct the development of the project. Upon careful analyses of major national reports, and, in addition to the study of major curriculum restructuring programs such as the AAAS Project 2061 (AAAS, 1989) and the NSTA Project of Scope, Sequence, and Secondary School Science (Aldridge, 1989), the Board generated numerous recommendations which translated into the following curriculum design recommendations:

- Life, earth, and physical science and the integration of the process skills, grades 1-6, must be developed from a strong philosophical and psychological-based framework.

- The content and skills as presented in the State's proclamation must be the "driving force" throughout the development of the inservice program.

- The content themes from Project 2061 should permeate the design project and form the fabric from which hands-on and minds-on activities emerge.

- The research-based instructional model within the inservice program must be flexible and incorporate only those components that may be easily implemented by teachers.

- The inservice model must form the template from which new lessons may be developed for students with a variety of special needs by teachers with little or no intervention from science curriculum specialists or supervisors.

- Objectives, strategies, development of special materials, and suggested dissemination and assessment procedures must be structured to reflect the basic attributes associated with scientific literacy.

- Alternative assessment strategies must be an integral component of the inservice package that will authentically assess learning outcomes in science.

- The program must embrace the components of contemporary elementary education such as hands-on, minds-on science, importance of assessing prior knowledge, constructivism, balance of content and skills, and the development of higher level thinking skills.

Rationale and Objectives

The project's ultimate goal was to develop and disseminate an exemplary elementary science inservice program that reflects the intent of Proclamation—No. 66 and to use the program to train all elementary school teachers in Texas. The objectives of the project included the preparation of a nonconsumable, self-contained, elementary inservice program composed of a resource strategy guide ("Facilitator's Resource Strategy Guide"), including printed materials and instructional videotapes and the training of instructional facilitators to conduct inservice workshops utilizing the guide.

The following curriculum design model, teaching for the enhancement of scientific literacy, provided the organizational format for TESIP (Zeitler & Barufaldi, 1988).

Note that the model in Figure 1 represents a triad of three attributes—attitudes, skills, and knowledge. Scientific literacy is a basic goal of elementary school science education and may be operationalized as the melding of attitudes, skills, and knowledge. This model provided the necessary guidance throughout the development of TESIP and ensured that TESIP would be developed in concert with the state curriculum guidelines as articulated in Proclamation—No. 66. This curriculum proclamation addresses the attitude component of the model as attitudes toward science as a discipline and attitudes toward scientific endeavors; the skills and knowledge components include those delineated in the proclamation as Essential Elements (process skills) and the recommended content focus for each grade level.

Components

TESIP consists of two components: a "Facilitator's Resource Strategy Guide" and two instructional videotapes. The Guide contains the following five modules. The Essence of the Texas Elementary Science Inservice Program, The 5-E Instructional Model for Teaching Elementary School Science, Alternative Assessment and Evaluation Strategies, Science Units, and, Trainer of Trainers (Barufaldi, Carnahan, & Rakow, 1991).

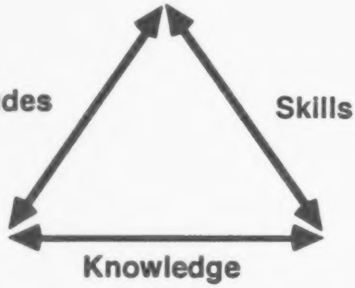


Figure 1. Teaching for the enhancement of scientific literacy model.

Module I. The "Essence" of the Texas Elementary Science Inservice Program presents a series of activities designed to enable the participants to describe the goals and objectives of TESIP and Proclamation—No. 66 and to operationalize scientific literacy. Numerous hands-on, minds-on activities are conducted by the participants that demonstrate "good" science teaching.

Example Activity: A Circle of Discovery

Objective: The participant will conduct a hands-on activity that reflects the essence of TESIP.

The participants are asked to stand and hold hands to form a circle and are instructed to guess the amount of time that it will take to pass (response) a hand squeeze (stimulus) throughout the circle of people. All guesses are accepted. One person is appointed and is designated as the "starter." Reaction time, the time it takes for the hand squeeze to pass throughout the circle, is recorded.

Additional trials are conducted. The participants are reminded that the collected baseline data enable them to make reasonable predictions, not spurious guesses. The participants also investigate the effects of additional variables on reaction time such as "reversing the flow of the squeeze," "closing one's eyes before the initial squeeze," or "doing a mild exercise," on reaction time.

Module II. The 5-E Instructional Model for Teaching Elementary School Science includes science experiences presented from a constructivist view (Table 5). Each stage of the 5-E model, adapted from the BSCS (1991) *Science for Life and Living*, is presented via activities and the use of an instructional videotape. This model is consistent with the constructivist learning theory in that learning throughout TESIP is structured in ways that encourages the construction of understanding of basic concepts over time. The participant conducts many activities that focus on the topic forensic science (fingerprinting); strategies move the participants through the instructional model beginning with their prior understanding, explore new experiences, and apply new information. This active process permeates the module as participants inquire, probe, discuss, rethink, and conclude. Each stage of the instructional model is correlated with a video segment of a teacher implementing similar science activities dealing with fingerprinting, using the 5-E instructional model, with intermediate school age children. This highly interactive process enables the participants to observe the characteristics and anticipated teacher and student behaviors of each stage of the model within a classroom setting (Table 6).

Table 5. Stages in the 5-E instructional model

ENGAGEMENT	Mentally engages and motivates students with an event or a question.
EXPLORATION	Hands-on, minds-on activities.
EXPLANATION	Helps students provide reasonable solutions and answers. Encourages them to listen and to further question.
ELABORATION	Events that help students apply the newly learned concept. Activities are used as vehicles to probe other unique situations.
EVALUATION	Students demonstrate an understanding of the concept or skill. Events help students to continue to elaborate on their understanding.

Example Activity: Engagement: "Solving a Crime"

Objectives: The participant will identify and describe patterns, become familiar with forensic science, collect evidence, and apply the engagement stage of the instructional model.

A large box with observable fingerprints is displayed in front of the participants. They are told that the facilitator has a door prize to be given away at the end of the workshop. In a dramatic way the box is opened; much to the facilitator's surprise the box is found empty! The participants discuss how one could collect the appropriate evidence to find the "criminal." The participants are told that the facilitator received a call from an informant who told the facilitator that the criminal is among the participants. The participants then review the engagement segment of the videotape of a sixth grade teacher conducting a Table

6. Engagement: Teacher and student behaviors

Teacher Behaviors	Motivates Creates Interest Taps into what the students know or think they know about the topic Raises questions and encourages responses.
Student Behaviors	Asks questions Demonstrates interest in the lesson
Examples	Puzzles Current Issues Discrepant events Situational events Mysteries Movies Poems

similar engagement activity. As participants view the videotape, teacher and student behaviors are identified and discussed that reflect the characteristics of the engagement stage of the model.

Module III. Alternative Assessment and Evaluation Strategies is designed to introduce participants to innovative techniques for the evaluation of students in science. The module has three focal areas: attitudes, skills, and basic knowledge. Examples of techniques for evaluating student progress in each of these areas are provided through activities and the use of an instructional videotape. Participants assess a problem-situation challenge, administer a Piagetian task, become familiar with clinical interviews, evaluate a hands-on experience, use an observation checklist, develop and use a grading rubric, and assess student attitudes toward science. As participants are introduced to innovative assessment and evaluation techniques, their attention is also drawn to an instructional videotape of elementary teachers employing the same assessment tactics with children in their respective classrooms. It is important to note that grading rubrics, or score sheets, are an integral component of this module and have been developed to assess behaviors that demonstrate acquisition of desired skills and attitudes and understanding of major concepts. Participants gain first hand experience with rubrics throughout this module.

Example Activity: Open-Ended Process Skills Test: How Would You Find Out if Bees are Attracted To Diet Cola?

Objectives: The participant will become familiar with a grading rubric and evaluate the videotaped responses of children discussing how they would conduct the test.

The participants view the videotape and use a grading rubric to grade the responses as the children speak (Table 7).

Module IV. Science Units presents a two-four week science unit, one for each grade, 1-6. The units, beginning with first grade include: What Lives in the Ocean?, Weather—A Study of Temperature and Wind; Sound; Plants and

Table 7. Grading rubric: Problem situation question

Explanation and Justification	0	Fails to select any alternative as an explanation
	1	Selects an alternative, but fails to justify a choice
	2	Selects an alternative and provides a reasonable justification for the selection
Procedure for Testing	0	Fails to develeop any type of plan
	1	Design will not allow comparison of variables to standard
	2	Design allows comparison of variables, but lacks sufficient control of variables to obtain learning data
Possible Explanations:		One point for each possible explanation given. Although teachers should be accepting of divergent ideas, it is reasonable to deny credit for ideas which are unrelated to the solution of the problem.
Score:	=	Explanation and Justification
	=	Procedure for Testing
	=	Possible Explanations

Pigments; Discovering Stars Through Models and Patterns; and Physical Science—Motion. The science units serve as templates which teachers use to develop additional units. Each unit, developed by master teachers on the Texas Project 2061 team, employs the 5-E instructional model, uses the appropriate innovative assessment strategies, incorporates the basic themes from the AAAS *Science for All Americans* (1989), reflects the "spirit" of contemporary science education, and supports the intent of the Texas Teacher Appraisal System (TTAS). TESIP provides numerous opportunities for teachers to demonstrate the performance requirements articulated and described in the TTAS instrument. Table 8 shows the design format for the science units and lessons within each unit.

Table 8. Components of science units

Introductions

Big Idea

Unit Goals and Lesson Objectives

Themese

Essential Elements Grid

Skills

Science Background

Lessons

Safety Information

Appropriate Timeline

Vocabulary Statement

Integration Statement

Assessment Statement

TESIP and Relationship to the Texas Teacher Appraisal System

The 5-E Instructional Model

Materials Grid

Teacher References

This module applies all of the previously presented components from TESIP and incorporates them into the lesson plans; participants may use the lessons as models or templates from which to develop additional science activities and units for their respective classrooms.

Example Activity: Unit Six: Physical Science, Grade 6: "Chiquita-Cheese and the World of Speed" or "How Can You Create and Change Motion?"

Objective: The participant will become familiar with the sixth grade science unit by conducting a series of activities dealing with motion.

Engagement Stage: The participants are presented with the question, "How can we explain why a magician can pull a tablecloth from under the place settings without upsetting them?" The facilitator conducts the following demonstration. A table is set and includes a plate, flatware, tumbler of water, a candelabra and a tablecloth. The tablecloth is quickly pulled from beneath the objects on the table, leaving (hopefully) the place setting intact. An open ended discussion is encourages the participants to provide reasonable explanations for the "phenomenon."

Module V. Trainer of Trainers is designed to provide the participants with the necessary leadership and organizational skills to present TESIP to elementary school teachers throughout Texas. The participants discuss topics such as characteristics of a "good" facilitator, advantages and disadvantages of co-facilitating, prioritizing goals, selecting an appropriate workshop/presentation, format/configuration, and evaluating workshop outcomes. Using cooperative learning groups the participants apply their basic understanding and develop an action plan to conduct a workshop. Table 9 shows the components of the "trainer of trainers model."

Table 9. Components of the "Trainer of Trainers" model

Setting the Stage	Pre-workshop preparation
Objectives	What the participants should learn
Taming	Introductions or ice-breakers
Norms	Workshop rules and location of facilities
Present	The presentation or explanation
Process	Checking for understanding of the presentation
Closure	Restating and summarizing
Evaluation	Checking to see if the objectives were accomplished and gathering feedback on the workshop itself

Training Workshops

During February, 1991, 100 facilitators (master teachers) were invited to participate in a three day TESIP workshop. Table 10 shows the format for a "typical" TESIP workshop. The facilitators represented all geographic areas of Texas and included at least five individuals from each of the 20 educational service center regions in the state. The facilitators were trained by members of the development team under the guidance of the project director. This initial training occurred in San Antonio, Houston, and Dallas. Each training session served as a model that facilitators eventually emulated in directing subsequent training sessions for teachers. Each facilitator received a copy of the resource guide, the instructional videotapes, and 40 additional copies of the module "Science Units." The facilitators made the commitment to conduct TESIP workshops with at least 40 teachers in their region; all facilitators have fulfilled this professional commitment.

Table 10. "Typical" agenda for TESIP workshop

Welcome	8:30 - 9:00
a.m.	
Warm Up "Taming"	9:00 - 9:15
Goals and Objectives	9:15 - 9:30
TESIP Feedback Survey	9:30 - 10:00
Shared-Pairs Activity Discussion of Feedback	10:00 - 10:30
Coffee Break	10:30 - 10:45
Shared-Pares Activity Written Critique of Each Module	10:45 - Noon
Lunch	Noon - 1:00
p.m.	
Cooperative Groups General Comments from TESIP Feedback Survey	1:00 - 2:00
Cooperative Groups Recommendations for Each Module	2:00 - 3:00
Total Group Discussion Instructional Videos	3:00 - 3:15
Break/Snack	3:15 - 3:30
Total Group Share-A-Thon (Activities that worked, Workshop configurations, Further facilitations, Misc.)	3:30 - 4:00
Evaluation of the Day	4:00 - 4:15

TEA has operationalized an extensive and ambitious staff development program and has recognized TESIP as a major priority for staff development. Initially, four educational service centers received funding during 1991 to train elementary teachers in their region. More than 5,000 teachers in Texas were trained during 1991. Presently all 20 educational service centers have trained staff members to continue with the training of elementary teachers using materials from TESIP. More than 20,000 teachers in Texas have been introduced to the TESIP program. Many universities throughout the state that are involved in teacher education are incorporating the major components of TESIP within their elementary science method's courses (such as the 5-E instructional model and alternative assessment strategies) and are using the science units as exemplary activities for hands-on, minds-on science. TESIP has been presented at the state conference of the Science Teachers Association of Texas and offered as a short course at the annual conference of the National Science Teachers Association.

Evaluation

A variety of measures was employed to evaluate the project. Some measures were tied directly to the completion of tasks as specified on the project timeline; some focused on the quality of the instructional materials developed; and, others addressed the effect of the inservice program on the instructional facilitators, and on the teachers trained by them. The evaluation plan focused on the efficacy of the project in meeting its objectives.

The completion of tasks as specified on the project timeline was fulfilled throughout the duration of the project. The quality and appropriateness of the materials were assessed throughout the project's development by science educators, master teachers, and content specialists. The videotapes and storyboards were assessed by experts in instructional design and communications. Modifications were made based upon the ongoing feedback from the master teachers and consultants.

Data collected from the facilitators were used to assess the effectiveness of the Facilitator's Resource Strategy Guide and the training sessions. The collected data suggest that the facilitators exited the three day training session with an understanding of: (a) how the instructional model can be used to teach elementary school science, (b) the attributes of scientific literacy and ways to nurture the development of a positive attitude toward science, (c) how the guide can be used to conduct inservice training programs in elementary school science, (d) how to develop alternative assessment procedures to test for skill and content attainment, (e) Proclamation—No. 66, and (f) how to integrate materials dealing with Essential Elements/process skills within an existing curriculum.

In addition, the facilitator's anxiety toward the teaching of science was measured before and after the three-day workshop by using a modified version of Speilberger's State Trait Anxiety Inventory (STAI), Form X-1 (A-State), (Westerback & Roll, 1982; Barufaldi, 1982; Barufaldi, 1987). The heading of the scale was changed from "Self Evaluation Questionnaire" to "How Do You Feel

About Teaching Science?". This scale of the instrument measures situational conditions or a transitory emotional state, which can be influenced by training. The scale contains 20 self report items (10 reversed and 10 nonreversed), such as "I feel secure," "I feel frightened," and "I feel self-confident," and respondents are asked to rate the intensity of their feelings on a Likert-type scale. The higher score indicating a higher level of anxiety. Studies have reported coefficient alpha internal consistency for the X Form in the range of .82 to .92 (Spielberger, Gorsuch, & Lushene, 1970). Means and standard deviations of pre- and post-instruments were computed; differences between means were analyzed by use of a t-test for correlated samples. The results of the analysis reveal that for the comparisons of means, the calculated t value was significant at the .01 level. One can then infer that the facilitator's anxiety toward teaching science became less intense, more positive, as a result of participation in the TESIP workshop.

In order to determine facilitators' concerns about TESIP and how concerns might change throughout the duration of the workshop, the facilitators were asked to respond to the following statement from the open-ended Concerns Questionnaire before and after the workshop; "In the space below, briefly discuss the major concerns that you have as you prepare to teach an elementary science unit or lesson. Place an asterisk in front of the statement that reflects your greatest concern." "Concern" is defined as the feelings, attitudes, thoughts, ideas, or reactions an individual possesses related to a new innovation such as TESIP. The Concerns Questionnaire is based on the Concerns-Based Adoption Model (CBAM) and is a valuable conceptual framework, which is used by those professionals responsible for implementing innovative programs (Hall, Rutherford, and George, 1979). It can be used in planning and delivering programs and in monitoring and facilitating teacher change and growth. This framework was developed at The University of Texas at Austin, Research and Development Center for Teacher Education, and resulted from many years of research on change in schools and colleges. CBAM provides an approach to the study of teacher change by focusing on the growth of individuals over time. Research resulted in the labeling of self, task, and impact concerns—the concerns of young teachers as they progressed from early preservice experiences to being experienced inservice teachers. The stages range from initial "information and self concerns" where individuals would be expressing such things as, "What is this science program and how will I be affected by it," to concerns related to "task," such as, "How can I make this new program work," to concerns for "impact," for example, "How will using this science program affect my student.". Teachers experience a variety of concerns at any one time; however, the degree of intensity of different concerns will vary depending on the teacher's knowledge and experience.

The facilitators' responses to the Concerns Questionnaire were analyzed, and the data revealed that, initially, the facilitators involved in the TESIP workshop demonstrated a variety of concerns. As was anticipated, their responses to the open-ended statement focused on "self concerns" and indicated that they wanted more information about TESIP; analysis of their written statements after the workshop indicated a concern about "task" or "How can I get TESIP program to work with teachers that I facilitate or within my own classroom?" These data are consistent with results from the CBAM program. Typically, individuals who are not yet users of an innovation such as TESIP or who are new to it will have concerns that are mainly about gaining information or about how using the innovation will affect them personally. Task concerns emerge as they begin to use the innovation. Then, when individuals become experienced and skilled, the tendency is for concerns such as "impact" to become more intense.

Currently, longitudinal studies are being conducted to determine the extent of curriculum (inservice program) alignment or fidelity. Curriculum alignment is a measure of the synergy that exists in the goals that are stressed from one target group to the next during the implementation process, namely between the developers and facilitators, facilitators and teachers, and teachers and their students (Barufaldi & Crawley, 1992). Information collected from the studies will aid in the description of relationships between and among the intended curriculum (attributes of the inservice program as designed by the developers), the interpreted curriculum (How do facilitators interpret the "essence" of the inservice program during their presentation of the program?), translated curriculum (How do teachers implement the components of the inservice program in the classroom?), and the experienced curriculum (Does the inservice program really make a difference with children?).

SUMMARY

The Texas Education Agency was responsive to the crises in science education by assuming a proactive role in recommending funding and the development of two noteworthy staff development programs in elementary science education. The results included successful implementation of two inservice programs, *Stepping* Into Successful Science Teaching (*Stepping*) and the Texas Elementary Science Inservice Program (TESIP). More than 20,000 teachers have been involved in the inservice training programs. Both qualitative and quantitative data have indicated that the programs have fulfilled their goals and objectives. The authors are confident that the programs also have provided elementary teachers with a unique set of experiences that will enable them to improve and enhance the teaching and the learning of elementary school science.

REFERENCES

Aldridge, B. G. (1989, March). *NSTA project of scope, sequence, and coordination of secondary school science*. Washington, DC: National Science Teachers Association.

American Association for the Advancement of Science. (1970). *Science—A process approach. Lexington, MA: Xerox Corporation.*

American Association for the Advancement of Science. (1989). *Project 2061: Science for all Americans*. Washington, DC: Author.

Barufaldi, J. P. (1982, Autumn). Science anxiety. *Discovery, 12*, Austin, Texas: The University of Texas at Austin.

Barufaldi, J. P. (1987). Basic studies on science anxiety and concerns of inservice and preservice elementary school teachers. In Pamela Fraser-Abder (Ed.) *Science Education Research in Latin America and the Caribbean* pp. 55-58. Trinidad: The University of the West Indies.

Barufaldi, J. P. (1989, February 14). A time of ferment in science, mathematics and technology education. Keynote address, Founders-Scholars Day Convocation, Marietta College, Ohio: Marietta.

Barufaldi, J., Carnahan, P., & Rakow, S. (1991). *Texas elementary science inservice program*. (Education for Economic Security Act, Title II, Project #00690401-04). Austin, Texas: Texas Education Agency.

Barufaldi, J. P. & Crawley, F. W. (1992). Evaluation of curriculum. Unpublished paper, Austin, Texas: Science Education Center, The University of Texas at Austin.

Biological Sciences Curriculum Study (1991). *Science for life and living*. Dubuque, Iowa: Kendall/Hunt Publishing Company.

Bybee, R. (1988). Contemporary elementary school science: the evolution of teachers and teaching. In A. Champagne (Ed.), *Science teaching: Making the system work* (Papers from the 1988 Forum for School Science) (pp. 61-103). Washington, DC: American Association for the Advancement of Science.

Cain, S. E. & Evans, J. M. (1984). *Sciencing: An involvement approach to elementary science methods* (2nd ed.). Columbus: Merrill.

Carnegie Forum on Education and the Economy. (1986, May). *A nation prepared: Teachers for the 21st century* (The report of the task force on teaching as a profession). New York: Carnegie Corporation.

George, K. D., Dietz, M. A., Abraham, E. C., & Nelson, M. A. (1974). *Elementary school science: why and how*. Lexington, MA: D. C. Heath and Co.

Gumnick, J. L. (1985, October). *The mathematics and science education crisis: Symptoms, causes, and possible cures* (Conference sponsored by the Oak Ridge Associated Universities, Publication of Proceedings). Washington, DC: U.S. Department of Energy, Office of Energy Research.

Hall, G., Rutherford, W., & George, A. (1979). *Measuring Stages of Concern About the Innovation: A Manual for Use of the SoC Questionnaire*. Austin, Texas: Research and Development Center for Teacher of Education, The University of Texas.

Johnson, D. W., Johnson, R. T., Holubec, E. J., & Roy, P. (1984). *Circles of learning: Cooperation in the classroom*. Alexandria, Virginia: Association for Supervision and Curriculum Development.

Jones, R. M. (1985). Teaming up. *Science and Children, 22*(8), 21-23.

Lewis, M. C. & Ostlund, K. L. (1986). *Stepping into successful science teaching*. San Marcos, Texas: Edwards Aquifer Research and Data Center, Southwest Texas State University.

Mechling, K. R. and Oliver, D. L. (1983). *What research says about elementary school science: Handbook IV* (Project for Promoting Science Among Elementary School Principals). Washington, DC: National Science Teachers Association.

Mullis, I. & Jenkins, L. (1988). *The science report card—Elements of risk and recovery, trends and achievement*. Educational Testing Service, New Jersey: Princeton.

The National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1983). *Educating Americans for the 21st century*. Washington, DC: The National Science Board Commission on Precollege Education in Mathematics, Science, and Technology.

Powledge, T. (1989, May 5). What shall we do about science education. *The AAAS Observer*. Washington, DC, pp. 1-2, 6-7.

Rowe, M. B. (1978). *Teaching science as continuous inquiry: a basic*. (2nd ed.). New York: McGraw-Hill.

SAVI/SELPH. (1981). Berkeley, California: University of California, Center for Multisensory Learning, Lawrence Hall of Science.

Shymansky, J., Kyle, W., Jr., & Alport, J. (1982, November/December). How effective were the hands-on science programs of yesterday? *Science and Children*, 20(3), 14-15.

Spielberger, C., Gorsuch, R. & Lushene, R. (1970). *STAI manual for the state-trait anxiety inventory*. California: Consulting Psychologist Press.

Texas Education Agency. (1991). *Proclamation of the State Board of Education Advertising for Bids on Textbooks—No. 66*. Austin, Texas: Author.

Tyson-Bernstein, H. (1988). The academy's contribution to the impoverishment of America's textbooks. *Phi Delta Kappa*, 70(3), 192-198.

Westerback, M. & Roll, C. (1982). *Anxiety reduction in preservice elementary teachers and the fulfillment of expectations for identification of minerals and rocks*. Paper presented at the 55th Annual Meeting of the National Association for Research in Science Teaching, Lake Geneva, WI.

Zeitler, Wm., & Barufaldi, J., (1988). *Teaching elementary school science: A perspective for teachers*. New York: Longman Publishing, Inc.

Chapter 10

The Oregon Consortium for Quality Science and Mathematics Education (OCQSME): Five Years of Collaborative Staff Development

Phyllis Campbell Ault
Charles R. Ault, Jr.

In the early 1980s, educational leaders expressed concern for the quality of science and mathematics education in our nation's schools (National Science Board [NSB], 1983; National Commission on Excellence in Education [NCEE], 1983). In response to this "crisis," educators from the Portland, Oregon, area representing public and private schools, the local science museum, and higher education pooled resources to form the Oregon Consortium for Quality Science and Mathematics Education (OCQSME). This collaboration recognized the benefits of sharing resources for staff development. OCQSME was able to conduct a larger scale inservice program for teachers than each district or school could provide separately. In addition, administrators and teachers overcame narrow views of educational problems with opportunities to share viewpoints and gain new perspectives from interaction with peers on a regional basis.

Annually, for several years, the Consortium invited nationally recognized speakers to address large groups of teachers assembled for a day of conferences and workshops on reforming science and mathematics education. As meetings and the exchange of ideas progressed, it became clear that current classroom teachers needed access to new skills, practices, and approaches to teaching. A model for staff development was sought that would provide such access to new approaches and training in needed skills as well as sustain support for promising practices on a regional basis.

Over the five-year period from 1988 to 1992, an innovative, teacher-centered model for staff development evolved, which relied upon regional resources and leadership in order to pursue nationally acclaimed goals for reform. The goals pursued in this model were simple yet elusive: provide support for teachers taking risks in trying new practices in science and math teaching, prompt teachers to consult with one another, and encourage teachers to assume leadership roles within their buildings. Embedded in this model were two themes: (a) teachers working with teachers, and (b) workshop extension over a large portion of the school year.

The model not only encouraged instructional innovations but also collaborative ventures on a regional scale among a great variety of institutions. OCQSME included more than a dozen school districts, several private and parochial schools, a science museum, and a college. Initially, the science museum took the lead in establishing the Consortium and defining common goals for its membership. The Consortium established an administrative team (the "Consortium Administrative Team" or CAT) consisting of representatives from each participating school district—either staff development personnel or curriculum specialists—as well as the Oregon Museum of Science and Industry (OMSI) and Lewis and Clark College. (See Figure 1 for a depiction of the model.)

The variety of institutions represented in the CAT ensured the availability of several forms of expertise. For example, from the outset, the OCQSME design could depend upon the CAT for providing up-to-date district needs assessments for staff development. Such needs assessments were critical to securing funding from the Eisenhower Mathematics and Science Program. In addition, based upon a long tradition of training teachers in hands-on science, the museum partner (OMSI) provided expertise on workshop presentation techniques. Lastly, the Lewis and Clark College representative ensured that offerings adhered to academic standards for earning a masters degree in education and that supporting links to mathematicians and scientists could be forged when needed.

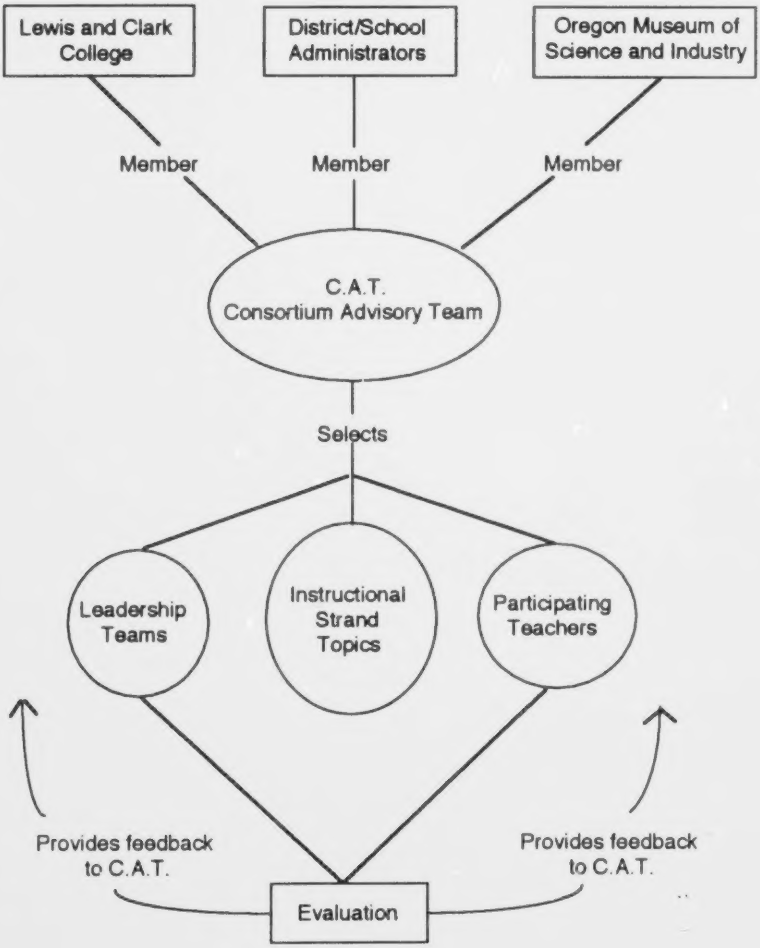
THE MODEL

Teachers must be intimately involved in the change process for it to succeed—the starting premise of OCQSME. The National Center For Improving Science Education report, *Developing and Supporting Teachers for Elementary School Science Education* (Loucks-Horsley, Carlson, Brink, Horwitz, Marsh, Pratt, Roy & Worth, 1989) articulates this premise clearly and emphatically. The report provides guidelines for "good staff development structures" congruent with those that shaped the OCQSME model. Such structures offer: "(1) support for the practice and refinement of new behaviors in the classroom; (2) opportunities for teachers to talk and work together to reinforce, problem solve, and encourage change; and, in many ways simply by their existence, (3) a clear message that the new behaviors are important and teachers are expected to use them" (p. 45). The Consortium model exemplified all three of these guidelines.

The OCQSME model also conformed in several respects to Bowyer, Ponzio and Lundholm's (1987) research synthesis of criteria for successful inservice staff development. Their synthesis analyzed the importance of active roles for administrators, opportunities for practice with innovations, in-class assistance ("coaching") for teachers, the value of teacher prominence in planning and presenting ideas, and the minimal workshop time needed to carry out such an agenda.

First, in keeping with advice from Bowyer, Ponzio, and Lundholm (1987), OCQSME plans called for a minimum of twenty instructional contact hours devoted to a single innovative "strand" (a topical section with 10 to 25 participants)

Figure 1. Components of the Oregon Consortium for Quality Science and Mathematics Education (OCQSME) model of staff development


Lewis and Clark College
District/School Administrators
Oregon Museum of Science and Industry
Member
Member
Member
C.A.T.
Consortium Advisory Team
Selects
Leadership Teams
Instructional Strand Topics
Participating Teachers
Provides feedback to C.A.T.
Provides feedback to C.A.T.
Evaluation

of teaching. Secondly, these hours were distributed as an "extended time-frame" over four months (winter and spring). Teachers received up to three full days of release time and met at Lewis & Clark College, OMSI, and their own buildings. Thirdly, at least one if not two classroom teachers—known as the "Leadership Team"—presided over each workshop "strand" as instructors.

Participants

Teachers from approximately 12 school districts and two private schools ranging from rural to suburban and urban have participated in the OCQSME inservice workshops over the last five years. Participants were either selected by building principals or self-selected out of interest. Elementary and middle school teachers dominated the enrollments.

During each of the first three years approximately 20 preservice students from Lewis and Clark College also attended. These were graduate students ranging in age from 23 to 40 years old—some in the midst of a career change. All were working as intern teachers (winter practicum, spring full-time student teaching) during their participation in OCQSME.

Teachers who participated were encouraged to take risks and act in leadership roles at two levels: as presenters and as participants. All participants (four of the five years of the model) came as pairs from a building, thus accepting the expectation they would work together to implement a change back in the classroom. As presenters, teachers comprising the Leadership Team received training in leadership skills and presentation techniques. For example, they joined the project evaluators and planners in defining goals and objectives for their own sections, then in abstracting these into general concerns for the project.

The model called for a pair of presenters in each workshop "strand"—topics of innovation such as "thematic instruction" or "design technology." Initially, one member of the team was assumed to have expertise in the innovation (a college professor, staff development administrator, or museum employee), the other—a teacher recommended by a district administrator—experienced in the grade level concerns of participants in the strand. As presenters gained experience in subsequent years and as the CAT responded to the evaluation data, this asymmetry disappeared. The presenters, when most effective, were truly equal partners who shared expertise.

The Oregon Department of Education (ODE) accepted this project as a means for awarding Eisenhower Act funds encumbered for the purpose of putting into practice the State's Common Curriculum Goals in Math and Science (Oregon Department of Education, 1988). The state requires schools to develop science curricula, for example, that conform to seven goals: (a) understanding fundamental concepts, (b) applying inquiry processes, (c) promoting interest in science, (d) developing manipulative skills, (e) appreciating the values that underlie science, (f) recognizing the interaction of science and technology with society, and (g) describing the characteristics of scientific knowledge. The State has accorded the highest priority to implementing "concept/process" instruction, an approach combining goals one and two (Oregon Department of Education, 1991). Concepts that dominate this approach include, for example, models and systems, interactions and changes, cycles and evolution. Processes conform to traditional objectives in science education: defining variables operationally, classifying, interpreting graphs, etc. The teacher development model described in this chapter incorporated these goals into all strand activities.

Furthermore, all of the strand topics introduced to teachers through OCQSME underscored the value of "hands-on science programs" (Shymansky, Kyle & Alpert, 1982) and student participation in "meaningful laboratory activities" (National Science Teachers Association [NSTA], 1991a). The teacher participants engaged in strand activities that ranged from engineering the cams of bobbing pull-toy heads, through averaging by restacking colored cubes, to recording how isopods respond to a temperature gradient. Not surprisingly, regardless of content and level, teachers expressed appreciation for learning new activities and in the strand evaluation often suggested that even more would be welcome. Given the success of the workshops, the innovative nature of the content covered, the scale of this model and its linkages among diverse school districts, outcomes of the project may prove informative to national efforts in curriculum change, such as AAAS' *Project 2061* (1989) and NSTA's *Scope Sequence, and Coordination Project* (NSTA, 1991b).

Description of the Strands

Teachers chose one of four or five workshop "strands" to participate in throughout the project. Strand options included topics such as design technology/ children's engineering, concept/process instruction in secondary science, and problem solving in primary grade mathematics. Each strand met for three sessions at about four-week intervals. Sessions were conducted over a full school day at Lewis and Clark College, local school sites, or OMSI. The three sessions of each strand were devoted to instruction, practice with activities, and sharing results of classroom implementations. Strand size ranged from 11 to 33 participants with most strands clustered around 20 participants. A total of 89 to 153 teachers were involved each year.

Strand topics and emphasis were chosen by the Consortium Advisory Team (CAT) composed of curriculum specialists or staff development administrators representing each sponsoring district or school. Strand topics reflected current needs as perceived by teachers and administrators at the district level. A needs assessment revealed the highest interest in implementing promising national agendas for reform. For example, each year one or more strands built upon implementing changes in instruction according to new standards from the National Council of Teachers of Mathematics (NCTM, 1989). In addition, strand topics embodied a holistic view of the science curriculum, one inclusive of design and engineering approaches to problem solving, integration of science with other subjects, and trends in interdisciplinary approaches to science curriculum (e.g., concept/process instruction).

Problem-solving and open-ended investigations were woven throughout the strand topics. All topics also reflected the CAT commitment to offering the workshops for a mix of grade level teachers. The composition of courses ranged from K-12 to a breakdown by elementary, middle school and high school teachers. Although specific titles and emphasis varied over the years, four innovative themes were included in each years' offerings:

1. The first of these four themes was in mathematics. The math strand each year focused on implementation methods for the National Council of Teachers of Mathematics standards for curriculum and evaluation. This topic was addressed in conjunction with the use of manipulatives and "hands-on" approaches to teaching mathematical concepts.

2. *Design Technology* (Dunn & Larson, 1990) or children's engineering was the second theme. Design principles which integrate concepts through "real-life" problem-solving characterized these strands.

3. A third theme was interdisciplinary approaches to thematic units of study. Instructional practices bridging, for example, science and math or language arts and social studies, were presented (cf., Jacobs, 1989; Resnick & Klopfer, 1989). Methods for secondary teachers to use cross-disciplinary themes were also addressed.

4. The fourth theme evident throughout the strands was the concept/process approach (Oregon Department of Education [ODE], 1991). In response to teacher needs, for the last two years emphasis has also been placed on integrating the Oregon Common Curriculum Goals with the strand topics.

Evaluation of the model

The OCQSME model introduced promising approaches to the teaching of science and mathematics to more than 600 teachers. In addition, over 30 Leadership Teams also participated in the OCQSME strands from 1988-1992. In depending upon local talent and leadership, it enhanced prospects for "grassroots" level change consistent with national agendas for improvement in science and mathematics teaching. The continued strong involvement of the twelve participating districts in OCQSME indicated the positive response teachers and administrators had to the project.

Each annual cycle ended with an evaluation process. Teachers who participated as workshop presenters—the Leadership Team—worked to define the objectives used for evaluation and participated in post-workshop interviews. Session participants completed questionnaires and shared descriptions of innovations tried in their classrooms—sometimes on videotape. The conclusions from this evaluation process were used to guide the design of the model for each subsequent year. Two questions guided evaluation:

1. How satisfied were teachers with the OCQSME model of staff development?

2. To what extent did participants attempt to implement the curriculum changes learned about through the OCQSME?

Upon completion of each strand session, evaluation data from participants was gathered through administration of a two-part questionnaire. The first part consisted of up to 31 Likert-style items designed with consideration of but not strict adherence to Koballa's (1984) guidelines. As previously discussed, the Leadership Team (i.e., the presenters) set objectives for each strand. These objectives were translated into Likert items and examined in modest degree according to several qualitative criteria as suggested by Koballa (avoid statements which imply authoritative viewpoint, keep to present tense or at least eschew future tense, restrict items to a single concern, avoid statements with a "yes-no" form of response, write in a clear, direct manner, reflect the attitude object explicitly, avoid double negatives and universals, keep statements brief).

In the first year, the Leadership Team reviewed the responses to the item pool after each of three workshop sessions. They suggested revisions, deletions, and additions to the pool. None of the Koballa criteria for quantitative sophistication of Likert instruments were applied. However, the project evaluators, the Leadership Team, and the CAT all concurred in the efficacy of the resulting Likert instruments. Perhaps more important to the continued improvement of the project through each cycle of evaluation were the participants' comments in response to several open-ended/short essay questions comprising the second half of the end-of-session questionnaires. Again, the Leadership Team and the CAT critiqued the phrasing of these questions after each session during the first year and when deemed appropriate in subsequent years. In this way, the model promoted teacher involvement in a research-oriented approach to their own teaching. In teaching their peers, teachers on the Leadership Team learned to reflect carefully on evaluation data. In implementing innovations, participants paused to reflect on successes and problems and communicated these insights to their strand leaders.

Feedback to make improvement of the model a continuous process made use of other data as well. Teachers receiving college credit for participation completed a detailed essay response survey at the end of the Consortium workshops. Preservice teachers during the first three years of the project visited several of their inservice colleagues' classrooms and shared observations of classroom practices as part of a required assignment. Leadership Teams for each year were interviewed in open-ended phone conversations soliciting primarily their experiences of problems, successes, and recommendations for improvement the following year. Lastly, administrators from each district gathered their own data on the workshop to use as a decision-making tool for continued involvement.

The primary purpose of the evaluation procedure was to improve the model in subsequent years. Both quantitative and qualitative data helped to gauge teacher success in leadership roles and willingness to take risks in making changes in math and science instruction. The model was an ambitious one, clearly intended to enhance professionalism as a means to reforming practices of math and science teaching. In summary, the evaluation procedures gathered data on the two broad themes of risk-taking and leadership in the form of assessing effective implementation of strand ideas and participant satisfaction with the format of each strand session.

Evaluation data provided for a formative evaluation and allowed for steady revisions of the model. Table 1 was designed for this chapter to reflect the type of quantitative feedback received by the Consortium Administrative Team from the Likert-style questionnaire items. Data in Table 1 are reported in percentage means for all three sessions, all strands by year. (Data from preservice participants have not been included in this table.) As in the tables presented to the CAT, the ratings on each item were condensed into and reported as simply the combinations of "agree" and "strongly agree" responses as a percentage of the number who answered the item. This procedure allowed for calculation of a single descriptive statistic easily interpretable at a qualitative level. Because the data are summarized as a mean of all three sessions for all five years, the mean does not adequately reflect what participants had learned upon completion of particular strands. Qualitative response data (open-ended questionnaire items and interviews with members of the Leadership Team) provided much better insight into this issue.

Open-ended response sections of workshop assessments were embedded in the workshop design to give teachers a genuine voice in the evaluation of the staff development model. Qualitative responses were collected by three means: (a) open-ended written responses to questions after each strand session, (b) a more extensive questionnaire completed by teachers who received graduate credit for their workshop participation and, (c) comments from phone interviews with Leadership Team members (i.e., strand instructors).

Three to five open-ended questions were asked after each strand session. This provided an opportunity for participants and strand leaders to give more detailed responses on some questions and comment on other aspects of the workshops. The responses from participants in the open-ended questionnaire section of the surveys indicated high interest in the use of manipulatives or a "hands-on" approach to teaching. Feedback also provided insight into teachers' strong appreciation for time to "actually do activities" and opportunities to share ideas across grade levels and schools. When reviewed over all three sessions, responses documented growth in participants' understanding of the strand topic. They moved from asking questions about content to asking for more information on assessment and implementation.

Teachers who elected to receive graduate-level college credit for Consortium participation were required to reflect on their learning by writing a series of short essays in response to a questionnaire received through the mail. Responses from these questionnaires indicated increased levels of risk-taking. Essays also provided information on teachers' personal application of workshop ideas in their classrooms as well as overall levels of implementation of strand innovations.

Over the course of five years, qualitative data highlighted additional workshop needs. Responses pointed the way to new strand topics (such as the need for an advanced session of *Design Technology*) and the inclusion of ideas across strands (for example integration of the Oregon Common Curriculum Goals and NCTM standards). Data also suggested organizational changes ranging from guest speakers to redesigning the selection process for strand participants (satisfaction greatly increased when teachers participated in strands that were their first

Table 1. Mean Percent Agree for All Strands and Sessions[a]

Question	Year				
	1988	1989	1990	1991	1992
n[b]	89	115	153	144	121
Inservice Effectiveness					
1. Overall, I valued session	99	100	97	98	100
2. Creative ideas and useful resources for teaching science/math were provided.	99	100	98	100	100
3. Appreciated cross-grade-level mix	97	94	90	95	
4. Learned planning	85	93	94	84	76
5. Learned accountability/ evaluation procedures	51	72	74	71	65
6. Motivated to take leadership responsibilities	86	95	92	94	100
7. Ready to take risks	91	96	92	98	98
Implementation					
8. Recognize administrative support	63	75	82	85	
9. Using ideas in teaching	82	90	95	97	
10. Involve other teachers in implementing strand ideas	39	48	53	64	
11. Consult strand partner on implementing activities	61	86	74	84	
12. Other teachers inquired on strand activities	41	41	36	47	

---

[a] Reported percentages combine "agree" and "strongly agree" responses as a percent of the number who responded to the item.

[b] Total number of participants.

choice). By adding qualitative response data to more quantitative Likert responses, the Consortium was more sensitive to participant suggestions and able to more closely match administrator, teacher, and instructor goals to the workshop presentation.

The model became a primary vehicle for accomplishing changes in mathematics and science teaching in classroom after classroom throughout a large metropolitan area. Teachers from different grade levels and school districts began to see common purpose in their different curricula. Implementation of innovations learned in the workshop was a primary goal of the Consortium Advisory Team. Several questionnaire items in the evaluation process yielded findings in this domain. "Administrative support," "using strand ideas in teaching," and "involving other teachers at school in implementing strand ideas" all showed steady growth in agreement over the years. Noticeably in 1988 only 39% of the participants agreed that they had "been active in involving other teachers in [their] school in implementing strand ideas." Agreement grew to 64% in 1991.

Teachers reported establishing a context for science learning through use of inquiry and thematic approaches and how to incorporate physical and visual representations of mathematical operations into daily instruction. Through OCQSME, the Portland region was introduced on a wide scale to Design Technology—a thoroughly interdisciplinary approach to teaching emphasizing principles of engineering design and rigorous cycles of defining and solving problems. Through OCQSME, teachers began to risk teaching mathematics from the perspective of finding patterns and solving problems rather than simply learning algorithms and improving computational skill. They learned to think of fundamental concepts/processes underlying science—systems, variables, models, for example—as the rationale behind their school science curricula.

Essential to learning workshop content was interaction with, leadership from, and support for their peers. The model did not call for faithful implementation of packaged activities as presented in session one. Instead, all teachers were encouraged to adapt innovations to their own circumstances according to their own best professional judgments. Sessions two and three in late winter or mid-spring saw participants gathered together to share notes, suggest modifications, and imagine novel ways to carry out their strands' agendas. By year three, teachers from buildings that had already sent teachers to OCQSME were clamoring for a chance to participate.

Attending the workshops with a partner enhanced the learning experience. Most participants "consulted with their strand partners frequently about implementing ideas developed in the strands." (Agreement ratings as reported on Table 1 ranged from a low of 61% in 1988 to a high of 86% in 1989.) Depending on strand and year, from one third to nearly one half of all participants consistently reported that other teachers in their buildings inquired about how to add strand activities to their teaching. The "optimal" contact time—20 instructional hours plus in-building consultations with a partner from the same workshop strand—was judged effective by teachers and administrators. The "extended time frame with repeated sessions on the same strand topic" design was extremely effective and supported throughout the five-year project by both the Consortium Administration Team and participating teachers.

Teachers working with teachers works—and works especially well when the vantage points of administrators, science and technology museum professionals, and professors of education combine to assist teachers in stretching their visions of excellent instruction in mathematics and science. The OCQSME experience suggests that models of change which accord teachers true professional status—where teachers lead and teachers make judgments about modifying innovations—have excellent prospects of success. The workshops built leadership readiness and willingness to take risks in teaching.

CONCLUSIONS

OCQSME evolved into an exemplary staff development program. It linked administrators and teachers, science museum and college, mathematics and science. The model provided continuity through each year and across years. It validated its basic premise—that teachers must first assume roles of leadership and assume risk in a climate of support if they are to fashion these same elements in their classroom settings. [Sarason (1990) argues this premise forcefully in *The Predictable Failure of Educational Reform.*] Because the OCQSME model adhered to this principle, administrator support was sustained and implementation levels were high, as suggested by the evaluation data.

Teachers, if they are to accept change, appear to benefit from identifying with those modeling the change, and from continued contact with the person in this leadership role. Additionally, support within their own building—even if only from a single other individual—is important. They also appear more likely to take risks in trying out an innovation if their own voices have been heard in shaping the form the innovation assumes in their own classrooms. Finally, such a context of taking risks and implementing change provides a valuable opportunity for sharing the talents of experienced teachers across experience and grade levels.

Although evaluation data documented the need teachers in each section had for "concrete lesson ideas," it also revealed a subtle trend. As teachers became competent in the strand topic and confident in themselves and their strand leaders, they began to ask for larger conceptual frameworks and rationales for why they were doing what they were enjoying so much. In essence, this model helped teachers see beyond clinical concerns and engage them in dialogue with their colleagues in reflection. They were willing to take risks, try change, and argue for its value—probably in the meantime taking the process of curriculum change along pathways not fully intended or anticipated by their district administrators. They had begun to experience those same conditions that OCQSME planners had hoped to create in classroom settings.

The collaboration among high level school administrators, personnel from a nationally recognized museum, and higher education leaders, validated for teachers the importance of the innovations they were trying, the larger context for this reform movement, and the potential for lasting support. Perhaps the best summary of the influence of the workshops on teachers was found in a short essay response from a teacher who received college credit for the Consortium:

> The workshop session helped me experience first hand how science is more than memorizing facts and getting 'one' answer. Children, like adults, will learn science more effectively if they are engaged in activities that focus on a concept and use one or more of the process skills. Ultimately they will be motivated and more self-directed to continue to 'experiment' and try things on their own to answer their own questions.

ACKNOWLEDGMENTS

We wish to extend our appreciation to Rob Larson, Northwest Regional Educational Laboratory (NWREL) and Anne Kennedy, Oregon Museum of Science and Industry (OMSI) for their guidance and assistance in evaluating the OCQSME project.

REFERENCES

American Association for the Advancement of Science [AAAS]. (1989). *Science for all Americans: Project 2061.* Washington, DC: AAAS.

Bowyer, J., Ponzio, R., & Lundholm, G. (1987). Staff development and science teaching: An investigation of selected delivery variables. *Journal of Research in Science Teaching, 24*(9), 807-819.

Dunn, S., & Larson, R. (1990). *Design technology: Children's engineering.* New York: Falmer Press.

Hays-Jacobs, H. (1989). *Interdisciplinary Curriculum.* Alexandria, VA: Association for Supervision and Curriculum Development [ASCD].

Koballa, T. (1984). Designing a Likert-type scale to assess attitude toward energy conservation: A nine step process. *Journal of Research in Science Teaching, 21*(7), 709-723.

Loucks-Horsley, S., Carlson, H. O., Brink, L. H., Horwitz, P., Marsh, D. D., Pratt, H., Roy, K. R., & Worth, K. (1989). *Developing and supporting teachers of eementary school science education.* Colorado Springs, CO: The National Center for Improving Science Education.

National Commission on Excellence in Education [NCEE]. (1983). *A nation at risk: The imperative of educational reform.* Washington, DC: U.S. Government Printing Office.

National Council of Teachers of Mathematics [NCTM]. (1989). *Curriculum and evaluation standards for mathematics.* Reston, VA: NCTM.

National Science Board [NSB] Commission on Precollege Education in Mathematics, Science and Technology. (1983). *Educating Americans for the 21st century: A report to the American people and the National Science Board.* Colemen, W. T., & Cannan, S., Co-chairs. Washington, DC: NSB.

National Science Teachers Association [NSTA]. (1991a). An NSTA position statement: Laboratory science. *Science and Children, 29*(2), 1-4.

National Science Teachers Association [NSTA]. (1991b). *Project on scope, sequence, and coordination of school science.* Washington, DC: NSTA.

Oregon Department of Education [ODE]. (1988). *Science education: Common curriculum goals.* Salem, OR: ODE.

Oregon Department of Education [ODE]. (1991). *Concept/Process-based science in the elementary school.* Salem, OR: ODE.

Resnick, L., & Klopfer, L., Eds. (1989). *Toward the thinking curriculum.* Association for Supervision and Curriculum Development (ASCD) yearbook. Alexandria, VA: ASCD.

Sarason, S. (1990). *The predictable failure of educational reform. Can we change course before it's too late?* San Francisco: Jossey-Bass.

Shymansky, J. A., Kyle, W. C., & Alport, J. M. (1982). How effective were the hands-on science programs of yesterday? *Science and Children, 20* (3), 14-15.

Chapter 11

Grow in Science: Explorations in Science, Learning, and Teaching

David E. Brown
Marilyn R. Sinclair

In this chapter, we describe a course for practicing teachers developed and taught collaboratively by representatives from a school district, a community college, and a research university. The course was designed to foster increased awareness on the part of the teachers of their own and children's learning when exploring natural phenomena. We purposely describe our efforts in these terms in order to cast them in an appropriate light. Although the efforts involve what could more conventionally be referred to as staff development and curriculum development, employment of these terms often carries metaphorical baggage that we explicitly reject—what could be called a "trickle down" metaphor of teaching.

Under this metaphor, "knowledge" comes from experts, who then transmit the knowledge to those less expert. Thus, scientists initiate scientific knowledge, which is then passed to teachers via college courses and textbooks, who then pass the knowledge on to their students. Similarly, knowledge of pedagogical approaches initiates with educational researchers, who then pass the knowledge on to curriculum designers. Teachers then employ professionally designed curricula much as technicians employ the specifications of engineers in constructing a product. Under this metaphor, children are somewhat incidental as simply the end recipients of externally generated input.

By contrast, we prefer an alternative metaphor, often called "constructivist," in which concern for students' ideas and individual and group knowledge construction takes central importance. Learning, here learning in science, is viewed as an active process of inquiry working toward a coherent, conceptual understanding of natural phenomena—a conceptual understanding that must be woven from existing conceptions, not "swallowed whole" from an authority. Because students need an environment that encourages this "weaving," the teacher's role changes from that of transmitter of other people's knowledge using other people's methods to that of facilitator of students' construction of meaningful understandings. The importance of community in this learning process cannot be overemphasized, because a forum for expressing one's ideas and receiving feedback is critical for the refinement of one's ideas.

Because of this constructivist orientation, we did not consider it possible to simply transfer to teachers (e.g., in the form of curricular materials with instructions for use) improved ability to engage students in fruitful inquiry. Just as students need to explore phenomena, teachers need to explore learning in inquiry-oriented situations. This course was designed to provide teachers with such experiences, first from the perspective of a learner, and then from the perspective of a teacher. In this chapter, we describe a summer course for elementary teachers in which they were immersed in a learning and teaching community for six weeks, and in which they immersed elementary children in a learning community during a summer science camp for

two of those weeks. Thus the teachers experienced explorations in science, learning, and teaching both as students and as teachers. We begin with an account of the development of the course, continue with an account of the course itself, and conclude with some indications of its effectiveness.

DEVELOPMENT OF THE SUMMER COURSE

The primary goal for *Grow in Science* was to foster, on the part of the participating teachers, an increased awareness of their own and children's learning when exploring natural phenomena. Because of the complexities involved in achieving this goal, we felt that it was important to draw on the strengths of three institutions. The course development, funded by an Illinois State Board of Education grant, represents a coalition of these three institutions: (a) Champaign Community Schools, (b) Parkland Community College, and (c) the University of Illinois. Representatives from each of these institutions met periodically over the course of the 1991-1992 school year to plan the summer course. Representatives from the Champaign Community Schools brought expertise in curriculum development, recent experience in innovative classroom teaching, and expertise in administering a summer science camp. Representatives from Parkland Community College brought expertise in engaging non-science-specialist adults in conceptually oriented activities in science. Representatives from the University of Illinois brought expertise in teacher education and in recent research on students' conceptions and learning in science. This coalition is presented as a model of collaboration, which might be fruitfully adopted elsewhere.

Central Ideas Guiding Course Development

As with any creative group effort, the development of *Grow in Science* was far from a linear process beginning with set goals and steadily progressing toward a more refined realization of those goals. However, there were some guiding ideas which, in hindsight, kept the development process drifting in an identifiable direction.

First, it has long been recognized that children need to *do*, not simply read about, science in order to advance toward full scientific literacy (Aldridge, 1992; American Chemical Society and the American Association of Physics Teachers, in preparation; Bredderman, 1983; National Science Resources Center, 1988; Rutherford & Ahlgren, 1990; Shymansky, 1989;). Second, it is especially important that time be spent to give students the opportunity to pursue investigations in some depth, rather than spending the time to "efficiently" cover large amounts of content (Aldridge, 1992; Duckworth, 1987; Duckworth, Easley, Hawkins & Henriques, 1990; Hawkins, 1965; National Research Council, 1990; Romance & Vitale, in press; Rutherford & Ahlgren, 1990). Third, students' existing conceptions and ways of reasoning must be taken into account. New knowledge and understanding will not result simply from passive reception of instruction from the teacher or textbook but rather will be a result of students building on existing knowledge and understanding (Driver, 1983; Driver, Guesne & Tiberghien, 1985; Gardner, Greeno, Reif, Schoenfeld, diSessa & Stage., 1990; Glynn, Yeany & Britton, 1991; Novak, 1987; Osborne & Freyberg, 1985; West & Pines, 1985). Fourth, it is increasingly clear that cooperative activities in small groups not only mirror more closely the working of actual scientists, but that they also have important affective and cognitive benefits (Bossert, 1988; Johnson & Johnson, 1991). Finally, teachers need to be viewed as professionals ultimately responsible for the learning environments in their classrooms rather than simply as technicians following externally imposed directions (Schön, 1983, 1987; Stenhouse, 1984; Hopkins, 1985).

Evolution of the Course

A few years ago, the elementary teachers and staff of Champaign Community Schools realized that the elementary students were not getting the opportunities in science learning that would encourage curiosity and exploration and set them on the right path to becoming scientifically literate citizens. They recognized the need, but found no curriculum materials that would satisfactorily assist them in bringing this to the students. Because satisfactory textbook programs were not available, the decision was made to develop hands-on science teaching units that would meet the needs of both the students and teachers of Champaign. The district agreed to this, and in 1989 the Franklin Science Center was established with a half-time Science Coordinator and a full-time secretary. A vision and a program began slowly to emerge, which provided students with increased opportunities for learning in the various domains of science and for the professional growth of their teachers. Plans were made for committees of teachers to write four interdisciplinary science units for each elementary grade level (K-5). These units were to be activity centered, with materials and supplies needed to teach a unit assembled in kits by the personnel of the Franklin Science Center and made available to teachers upon request. At the present time, fifteen units have been completed and the response of the teachers using them has been very positive. Some titles of units completed and used in the classrooms are: "My Five Senses" (K), "Magnets" (gr. 1), "Butterflies and Moths" (gr. 2), "Mystery Powders" (gr. 3), "Batteries and Bulbs" (gr. 4), and "What's the Matter?" (gr. 5). These units have been written with the help of personnel from the Department of Curriculum and Instruction (University of Illinois), the Division of Natural Sciences (Parkland Community College), and practicing scientists from the Illinois State Scientific Surveys. Thus, this program has produced curriculum, improved learning for students and teachers, and a united effort of diverse educational agencies in the community to improve scientific literacy.

Early requirements of the program were for teacher time to develop the curriculum materials and for copies of curriculum resource materials for use in this work. The writing of elementary science units began with teacher release time during the 1989-90 school year. It was continued during the summer of 1990 by providing writing time to teachers. This work was carried out at the Science Center with the help of the Science Coordinator and secretary. The resulting curriculum units were piloted in classrooms the following school year and then edited, revised, and produced for the rest of the district's classroom teachers. These science units, along with the supplies for student hands-on involvement, were provided to all elementary teachers.

It quickly became apparent that the provision of teacher-written materials and the supplies to teach those materials was not, alone, sufficient to meet the needs for improving the science learning going on in the classrooms. Teachers' perception of, knowledge of, and comfort with, science teaching needed upgrading, along with the curriculum. To begin to meet this need, during the 1990-91 school-year, two graduate-level courses were specially developed for elementary teachers and offered through the University of Illinois, Department of Extramural Courses. The courses were designed to help classroom teachers learn some basic science concepts and to review some basic principles of science learning and curriculum development. The first course, aimed to provide instruction and experiences in some basic concepts in both physical and life science, met in the Fall of 1990 and was taught by Parkland College instructors, using the laboratories and facilities there. The second course met at the Franklin Science Center in the Spring of 1991 and was led by a university professor in Science Education. During this time, in conjunction with the objectives of the course, the teachers wrote curricula appropriate for classroom use that could be incorporated into the Champaign elementary science program. Certain of these units were then piloted in a summer science camp with elementary children.

Although this first attempt at collaboration in providing the courses was somewhat successful, there were several aspects that were targeted for improvement. These generally fell under the need for a more integrated experience for the teachers in which their own inquiry, instructional planning, engaging children in inquiry, and reflection on their own and the children's learning were all part of a single summer course rather than being spread over separate experiences.

DESCRIPTION OF THE SUMMER COURSE

Purpose and Design

As mentioned previously, the primary purpose for *Grow in Science* was to foster, on the part of the participating teachers, an increased awareness of their own and children's learning when exploring natural phenomena. To accomplish this, the course gave the teachers an opportunity to engage in inquiry themselves, to engage children in inquiry during a summer science camp, and to spend a significant amount of time reflecting systematically on their own and the children's learning in an environment that minimizes risks and maximizes opportunities for creativity. In this course, learning in science is viewed as resulting from an active process of inquiry in which students (and scientists) construct new understandings based on an interplay between their existing conceptions and their social and physical environment. This view contrasts sharply with a view of science and science learning which holds that science is a body of discrete bits of factual knowledge received from authorities, and thus science learning involves committing these bits of knowledge to memory. Because of the former perspective, a significant part of the course was spent engaging in inquiry activities and in discussing ways of helping children engage in such activities. The teaching approach that was modeled could be called "conceptual inquiry," indicating that students were encouraged in the process of inquiry (self-motivated, open-ended investigation of the phenomena), but were also given guidance at key points in the construction of concepts that illuminate the phenomena.

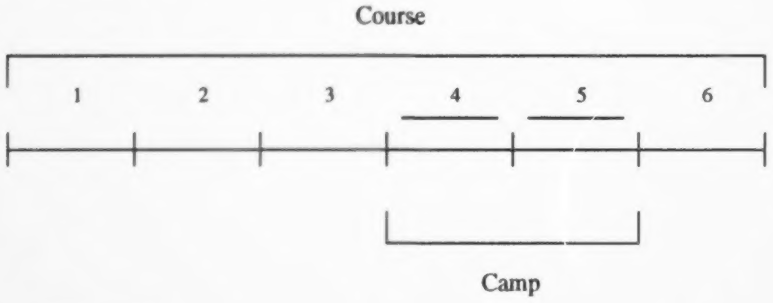
Grow in Science was not an extended in-service on a particular curriculum. Although the teachers emerged from the course with some very specific activities and techniques to use with their children the following year, these were *not* activities and techniques mandated by a particular curriculum or approach. Rather, these specific activities and techniques grew out of their experiences of what worked for them, both in their own activities and the activities in which they engaged children during the science camp.

While the course was intensive enough to warrant graduate credit, we believed that an evaluative atmosphere would detract from the optimal environment needed for their reflection on their own learning and the learning of the children. As such, the course was graded on a satisfactory/unsatisfactory basis.

Activities

The first three weeks were spent engaging in science activities with the teachers and in reflection on those activities. There was also time for preparation of activities for a summer science camp for children, making use of the extensive collection of hands-on curriculum materials available at the Franklin Science Center. During the summer science camp (the fourth and fifth week of the course), the teachers engaged children in science activities in the morning and reflected on these activities in the afternoon. Videotapes of activities in the science camp classes were used extensively to facilitate this reflection. The final week was spent in concluding discussions and in ways of implementing new instructional ideas in their own classrooms the following year. See Figure 1 for an overview of this structure. Each of these components are described in more detail below.

Figure 1: Overall structure of the course



First three weeks
  - Time for open-ended investigations of phenomena (e.g., crickets, kitchen chemicals)
  - Readings focusing on a constructivist perspective on learning and teaching
  - Time for reflection on the readings and on their own learning
  - Time for preparation for teaching in the science camp, making use of the extensive collection of innovative curriculum materials at the Franklin Science Center

Science camp (fourth and fifth weeks)
  - Mornings
    - Engaging children in investigations of natural phenomena
    - Focusing on children's learning, daily recording thoughts, observations, and reflections in an interpretive diary
  - Afternoons
    - Group discussions of the day's activities
    - Meetings in small groups to view videotapes of children
    - Reflection on important issues

Final week
  - Further viewing of videotapes from the summer camp
  - Consideration of further issues in a constructivist perspective on learning and teaching
  - Discussing constraints to inquiry in regular classrooms and brainstorming possible solutions

During the first two weeks, the course instructors engaged the 20 participating teachers in numerous activities, from experimenting with light and color, to mixing common kitchen substances, to observing crickets and earthworms in clear, two-liter plastic bottles. Following is a description of a "typical" day incorporating the important elements from the first two weeks. We began with a discussion of readings, first in their small groups and then in the large group. The readings chosen were richly illustrated with instances of actual learning in situations in which students were able to ask and begin to answer their own questions, and in which the emphasis was on conceptual understanding rather than memorization of facts. Then, the instructor from Parkland College introduced the activities for the day—exploring the properties of ordinary household chemicals such as baking soda and Kool-Aid. In order to assist the teachers in their explorations, he had prepared a short list of questions to spark investigation. The self-motivated investigations took the greater part of the three-hour period. During this time the instructors circulated, feeding into the inquiry with questions and comments. Near the end of the time for investigations, each group prepared a poster to communicate their explorations and findings to the larger group, and a "scientific conference" was held during which each group shared its poster. After this, a class discussion was held focusing on the participants' reflections on their own learning, and time was provided for them to record their personal reflections in a journal.

The third week of the course was spent in guided preparation of activities for the summer science camp, which was held during the fourth and fifth weeks of the course. This third week was held at Franklin Science Center, which houses a substantial collection of resources for teaching hands-on science, both materials and curricula. During this time, the teachers worked in "instructional groups," consisting of four teachers, each of whom had participated in a different "learning group" during the first two weeks. In this way, each member of the instructional group could contribute insights gained from their group work during the first two weeks. Members of each instructional group then paired up to teach individual classes during the science camp, described below.

One of the most important parts of the experience was involvement in the summer science camp. Although the teachers often chose to adapt many of the activities from the first three weeks to use in the science camp, there was a great deal of latitude for their own creativity. Many of the constraints present in classroom teaching were removed so that they had the freedom to try new ideas and to focus attention on the children's learning. For example, each class consisted of about 16 children with two teachers from the course, so classroom management problems were minimized. There were also three certified teachers hired as "floaters" to help with classroom management issues. Materials were all provided, and there were several people around who could serve as "gofers" to help with materials management. When an unexpected materials need arose (e.g., because of a student suggested experiment), in most cases commonly available materials were provided for the following day. There was no set curriculum to get through in the two weeks—if something took far longer than expected because of students' interest, all to the good! If something "flopped," there was a supportive community to help in articulating *why* the activity or approach "failed." As such, these "failures" were some of the most important learning experiences. The important point is that the teachers could use this low-risk environment as an opportunity to take risks, to try new things, and to be creative.

Also during this time, in the afternoons the participants met to reflect on the events of the morning science camp. Several video cameras were available for videotaping both large group interactions and small group investigations during the science camp. Use of this videotape data facilitated reflection on the children's learning. Of particular importance during this reflection were questions such as: What new awarenesses have the children developed as a result of the activities? What aspects of the activities were most important in bringing about these new awarenesses? If there were frustrations, what brought them about? Were they necessary, or could they have been avoided? If necessary, why? If not, how could they have been avoided? How could the activity have been structured differently to better enhance learning? What kinds of questions did enhance or would have enhanced the children's learning? Were children learning even when no teacher was immediately present during a small-group's investigation?

During the final week, participants had further opportunity to reflect on these and other questions. Of particular importance during the final week were discussions and group problem-solving of ways to overcome obstacles to implementation of conceptual inquiry in their own, less ideal settings the following year. The teachers met this challenge with gusto, producing a list of about 30 potential obstacles, from lack of materials to professional jealousy. Small groups then met to propose potential solutions to these constraints, and solutions were proposed for each of the barriers. After this exercise and other discussions the final week, the predominant mood was one of anticipation at the challenge of implementing the ideas in their own classrooms.

INDICATIONS OF EFFECTIVENESS

Data sources examining the effectiveness of both the overall course and the summer camp include the following: notes and videotapes of course discussions and inquiry activities with the teachers, copies of teachers' papers reflecting on their own learning during the first two weeks, observation notes of classes during the summer science camp, extensive video data focusing on small groups of children from five video cameras in operation during the summer camp, notes and some video of the teachers' reflective discussions during the afternoons of the science camp and during the final week, copies of the teachers' interpretive diaries focusing on the children's learning during the camp, parental evaluation forms from the science camp, copies of the teachers' summary papers focusing on their own and the children's learning, and teachers' anonymous course evaluation forms.

Analysis of this large amount of data is still in the early stages. However, all indications so far of the effectiveness of both the course and the science camp indicate significant growth in the teachers' and the children's willingness and ability to engage in fruitful inquiry, and in the teacher's willingness and ability to structure classroom environments to encourage inquiry. Perhaps the most predominant form of feedback from the teachers has been that of an extremely positive response to the learning environment of the course in which they were treated as thinking individuals whose questions and ideas deserved respect. Many indicated that it was this aspect of the course that was most revolutionary to them and made them want to engender this kind of atmosphere in their own classrooms, especially after seeing the kind of positive learning environment this respect for children's ideas created in the summer science camp.

Although indications from the course have been overwhelmingly positive, it is still unclear whether the teachers will be able to engender the same kind of learning environment in their classes during the year because of greater constraints. However, if the teachers are able to overcome personal and external barriers and create the same atmosphere that they and the children in the science camp have responded to so positively, there seems to be little doubt that children will have a greatly improved learning environment. From initial survey data from the teachers, many seem to be well on their way to overcoming these barriers. To date (October, 1992), 17 of the 20 teachers have responded to a survey mailed out two weeks ago asking about implementation of new ideas in their classrooms. All 17 indicate specific ways in which the course has made or will make a substantial difference in their own teaching.

CONCLUSIONS

There are several aspects of the *Grow in Science* project which, if not unique, are uniquely implemented and worth sharing.

- A close collaboration between the science coordinator and teachers of a school district, science instructors at a community college, and science education professors at a research university.
- An integrated, intensive summer course for practicing teachers which includes experiential learning in science, reflection on their own learning, preparing for and teaching in a summer science camp, and reflection on the children's learning during the camp.
- Modeling of a conceptual inquiry approach in which students are encouraged in the process of inquiry (self-motivated, open-ended investigation of phenomena), but are also given guidance at key points in the construction of concepts that illuminate the phenomena.
- An emphasis on the development of a teaching and learning community including teachers, teacher educators, scientists, and children. In this community, teachers are informed consumers of research and curricular ideas rather than simply technicians following the specifications of others.

In conclusion, it appears possible to conduct courses for practicing elementary teachers designed and taught by representatives from several institutions, each bringing unique strengths to the effort. Such a project appears to have a major impact on teachers' conceptions of science learning and teaching.

ACKNOWLEDGMENTS

Special thanks go to those who have been involved in the development and teaching of the summer course. These include, in addition to the authors and in alphabetical order, Diana Beck, Vic Cox, Andrew Holm, Jim McGaughey, Charlie Weller, and Edee Wiziecki.

REFERENCES

Aldridge, B. G. (1992). Project on Scope, Sequence, and Coordination: A new synthesis for improving science education. *Journal of Science Education and Technology, 1,* 13-21.

American Association for the Advancement of Science (1989). *Project 2061: Science for all Americans.* Washington, DC: Author.

American Chemical Society and the American Association of Physics Teachers (in preparation). *Report on the School Science Curriculum Conference.* Washington, DC: Authors.

Bossert, S. T. (1988). Cooperative activities in the classroom. *Review of Research in Education, 15,* 225-250.

Bredderman, T. (1983). Effects of activity-based elementary science on student outcomes: A quantitative synthesis. *Review of Educational Research, 53,* 499-518.

Driver, R. (1983). *The pupil as scientist?* Milton Keynes: Open University Press.

Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's ideas in science.* Milton Keynes: Open University Press.

Duckworth, E. (1987). *The having of wonderful ideas and other essays on teaching and learning.* New York: Teachers College Press.

Duckworth, E., Easley, J., Hawkins, D., & Henriques, A. (1990). *Science education: A minds-on approach for the elementary years.* Hillsdale, NJ: Erlbaum.

Gardner, M., Greeno, J. G., Reif, F., Schoenfeld, A. H., diSessa, A., & Stage, E. (Eds.). (1990). *Toward a scientific practice of science education.* Hillsdale, NJ: Erlbaum.

Glynn, S. M., Yeany, R. H., & Britton, B. K. (Eds.). (1991). *The psychology of learning science.* Hillsdale, NJ: Erlbaum.

Harvard Graduate School of Education. (1990). When kids do science. *The Harvard Education Letter, 6*(3).

Hawkins, D. (1965). Messing about in science. *Science and Children, 2*(5), 5-9.

Hopkins, D. (1985). *A teacher's guide to classroom research.* Philadelphia: Open University Press.

Johnson, D. W., & Johnson, R. T. (1991). *Learning together and alone: Cooperative, competitive, and individualistic learning.* (3rd Ed.). Englewood Cliffs, NJ: Prentice Hall.

National Research Council. (1990). *Fulfilling the promise: Biology education in the nation's schools.* Washington, DC: National Academy Press.

National Science Resources Center. (1988). Teaching elementary science: An agenda for action. *NSRC Newsletter, 1*(1).

Novak, J. D. (Ed.). (1987). *Proceedings of the Second International Seminar, Misconceptions and Educational Strategies in Science and Mathematics.* Cornell University, July 26-29, 1987.

Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science.* Birkenhead, Australia: Heinemann.

Romance, N. R., & Vitale, M. R. (in press). A curriculum strategy that expands time for in-depth elementary science instruction by using science-based reading strategies: Effects of a year-long study in grade four. *Journal of Research in Science Teaching.*

Rutherford, F. J., & Ahlgren, A. (1990). *Science for all Americans.* New York: Oxford University Press.

Schön, D. (1983). *The reflective practitioner: How professionals think in action.* New York: Basic Books.

Schön, D. (1987). *Educating the reflective practitioner.* San Francisco: Jossey-Bass.

Shymansky, J. A. (1989). What research says...about ESS, SCIS and SAPA. *Science and Children, 26*(7), 33-35.

Stenhouse, L. (1984). Artistry and teaching: The teacher as focus of research and development. In D. Hopkins, & M. Wideen (Eds.) *Alternative perspectives on school improvement.* Lewes: Falmer.

West, L. T. H., & Pines, A. L. (Eds.). (1985). *Cognitive structure and conceptual change.* Orlando: Academic Press.

Wolf, D., Bixby, J., Glenn, J. III, & Gardner, H. (1991). To use their minds well: Investigating new forms of student assessment. *Review of Research in Education, 17,* 31-74.

Chapter 12

Placing Gender on the Science Teacher's Agenda: A Program for Professional Development

Lesley H. Parker

During the past 15 years, the unequal participation of males and females in school science and mathematics has attracted considerable attention worldwide. Since 1981, for example, the contributions to six biennial international Gender and Science and Technology (GASAT) conferences have raised and addressed concerns regarding this inequity (e.g., Rennie, Parker & Hildebrand, 1991).

Social justice and economic and philosophical imperatives drive many of the concerns expressed and underpin many of the interventions initiated. It is argued, for example, that both developed and developing countries need to increase the number and the quality of their graduates in science, in order to maintain a competitive edge in the world's changing commercial, economic, and technological environments. It is also argued that science and science education need to be more inclusive of a wider variety of perspectives. Specifically, the need for reforms to make science education more gender-inclusive is emphasized, and particular emphasis in this regard is given to the roles and responsibilities of science teachers. Recently, for example, the report on women's education commissioned by the American Association of University Women highlighted the lack of encouragement given to female students to continue in science. It recommended that "teachers, administrators and counselors must be prepared and encouraged to bring gender equity to every aspect of schooling" (AAUW, 1992, p 85).

In this context, the availability of teacher development programs focusing on gender issues in science education is critical. This chapter describes the development and evaluation of one such program that has been successful in enhancing teachers' knowledge, skills, and understandings of the significance of gender in their professional practice. This program is designed as two units—an introductory unit and a more sophisticated unit—which, although sequential, can be undertaken independently of one another.

Teachers can elect to take the unit(s) purely for personal development purposes, or they can elect to complete them for professional development purposes. For example the units are recognized for credit towards a teacher's designation as an "Advanced Skills Teacher," or for credit towards university degree programs. The latter include the graduate programs offered by the Science and Mathematics Education Centre (SMEC) at Curtin University of Technology in Western Australia (Doctor of Philosophy, Doctor of Science Education, Master of Science (Science Education) and Postgraduate Diploma in Science Education).

Each unit is designed to be undertaken in any one of a variety of modes, depending on teachers' needs and circumstances. The modes include:

1. 15 weekly two-hour sessions (suited to those able to attend Curtin University).
2. Self-paced study using a set of material (including a reader, an audiotape, a videotape and a step-by-step guide) suited to students situated some distance from Curtin, and therefore undertaking study externally, by correspondence.
3. A concentrated course covering one week of full-time tuition at Curtin and related assignments completed by correspondence.

BACKGROUND TO THE DEVELOPMENT OF THE UNITS

The context for the development of the units was created when, in 1988, the Australian government selected Curtin University as the site of the national Key Centre for Teaching and Research in School Science and Mathematics. The overall aim of the Key Centre was essentially to provide teacher development programs targeted at improvement in the quality and level of students' participation and achievement in school science and mathematics, with particular emphasis on increasing gender equity in science and mathematics education. The organizational structure for achieving this aim focused on four kinds of teacher development activity, covering graduate teaching, research, publication, and national workshops.

The unit(s) on gender issues were conceived initially as components of the graduate teaching and national workshop activities. The introductory unit was designed in 1989-90 and piloted during the second semester in 1990. As reported by Parker (1991), the pilot served to identify strengths and weaknesses of the unit, and highlighted the need for both an introductory and a more challenging unit. The structure, content, and assessment tasks of the introductory unit were therefore modified to make it more genuinely "introductory," and a new unit, suitable for students at the doctoral level, was developed during 1991. A number of international experts in the area who were consulted regarding the content of the units provided valuable suggestions.

This chapter, while referring to design, implementation, and evaluation issues pertaining to both units, focuses in greater detail on the introductory unit (offered at Master's and Post-Graduate Diploma levels), because, at the time of writing, the doctoral level unit is still in the pilot phase. The developmental and evaluative activities reported here were supported by a grant from the Curtin University Mini-Fellowship Scheme, a scheme that aims to improve the effectiveness of teaching in undergraduate and graduate programs.

Identifying and Addressing the Needs of the Target Group

From knowledge of the overall profile of the science teaching force in Australia (Department of Employment, Education and Training, 1989), the target group for the introductory unit was known to be practicing science teachers or educational administrators, varying in age from the mid-20 to mid-50, and highly motivated to update their knowledge and expertise in the area of gender equity. Previous experience had indicated that the target group's paramount need was of an essentially practical nature. As practitioners aiming to take account of gender in their everyday practice, the members of the group needed knowledge and skills relevant to their decisions about science curriculum content, teaching strategies, and assessment strategies. The curriculum design challenge was to provide such skills and insights with a sufficiently theoretical basis to enable participants to generalize their experiences and to recognize the ideology underpinning their own and others' actions and choices.

In a curriculum-design sense there are essentially two alternative models available for incorporating special issues such as gender in a course of study—the autonomous model and the integrationist model (Bowles & Duelli Klein, 1983). Each has its advantages and disadvantages and there is considerable ongoing debate about which is the more effective. As indicated by Parker and Hillman (1990), the integrationist model, which in this case would have involved the incorporation of gender issues as core material in every unit and workshop offered by SMEC, would have ensured the exposure of all, however unwillingly, to the new knowledge and skills. Its advantages lie in its universalism, its disadvantages in its lack of voluntarism. The latter disadvantage is overcome in the autonomous model, which provides the special issues on an elective basis.

Although the autonomous model does have the potential disadvantage of possibly reaffirming the marginality of the special issues and of setting up a situation of "preaching to the converted," it has several advantages. For example, the instructional setting created by a committed group, with shared goals, tends to be one that facilitates high quality and lively exchanges among participants, and an atmosphere in which they have control over their own knowledge-making. They are able to concentrate their energies on a separate subject, with its own identity, and to give sustained and deep thought to meeting the challenges raised. In this case, for both administrative and educational reasons, the autonomous model was the one on which the gender issues units were based.

DEVELOPMENT OF THE INTRODUCTORY UNIT

A somewhat classical approach to curriculum development was taken in the case of the introductory unit, with delineation of the overall aim of the unit seen as the first task in its development. After considerable discussion amongst colleagues and with reference to the needs of the target students, it was agreed that the unit should aim to explore a range of theoretical and practical issues relevant to the relationship between gender and mathematics and science. In stating this aim, a deliberate attempt was made to avoid a narrow and somewhat simplistic focus on, for example, the under-representation of women in science and mathematics. The issues worthy of study and investigation were seen to arise from the complex interaction between gender, science and mathematics, and the gendered nature of knowledge. Thus, the unit was intended to have a strong sociological emphasis addressing this complex interaction and its personal and practical implications, an approach aligned strongly with feminist pedagogy (Laird, 1988).

The plan of the unit involved challenging participants initially with a variety of statements expressing beliefs about the relationship between gender, science, and mathematics. Compelling statements from the history of women's education were selected for this challenge, as quoted for example in Tyack and Hansot (1988) and Hunt (1987). Attention was drawn to the recurrent nineteenth century argument that the study of mathematics and science would be injurious to women's health (or, more specifically, to their reproductive capacity). The power carried by these arguments at the time was emphasized, with reference to their widespread effects, even on educators clearly committed to the education of women. Dorothea Beale, for example, the Headmistress of a famous and progressive British girls' school, declared:

> I do not think that the mathematical powers of women enable them generally—(their physical strength, I dare say, has a great deal to do with it) to go so far in the higher branches, and I think we should be straining the mind (which is the thing of all things to be most deprecated) if we were to try to force them to take up such examination. (Quoted in Clements, 1989, p 21).

The issue of the much more subtle legacy of these arguments as part of the educational culture of twentieth century education was raised. Participants were informed that the unit would explore some of the present-day practical consequences of such beliefs and arguments and would provide an introduction to some of their complex theoretical ramifications. It was emphasized that the unit aimed to bring participants to a point where they could argue, in relation to gender equity, the pros and cons of various approaches to mathematics and science education, with importantly, their argument based on a wide range of research findings, not just on their own personal beliefs.

Specifically, the stated outcomes of the unit indicated that upon completion, it was expected that participants would be able to:

1. Demonstrate knowledge of, and ability to read critically, a variety of literature relevant to the relationship between gender and science and mathematics.

2. Identify, discuss and apply explanatory models relevant to gender differences in science and mathematics education.

3. Critique a range of educational initiatives in terms of their relevance to the relationship between gender and science and mathematics and their effect on the science/mathematics education of females and males.

4. Apply and generate practical ideas and techniques for facilitating gender equity in science and mathematics.

Textbooks for the unit were selected using a number of criteria. They were required to be recent, relatively inexpensive and readily available, and, as a group, provide rigorous coverage of the issue of gender in both science and mathematics education. Four texts (Fraser & Giddings, 1987; Leder & Sampson, 1989; Treagust & Rennie, 1989) were eventually selected, and were supplemented with a Reader containing 23 selected readings (many of which will be referred to throughout this chapter). Ultimately, the intention is to produce a single textbook to support the unit. Work is in progress on an edited book of readings, with contributions from several key researchers in the area of gender and science and mathematics (Parker, Rennie & Fraser, in preparation).

The style of delivery appropriate to the philosophy and ethos of this unit was already well established in SMEC. Essentially, this involves a collegial, collaborative approach with an emphasis on personal growth, reflection, attainment of personal goals, and respect for the ideas of others. Internal sessions are organized in a manner that allows ample opportunity for sharing and discussion of knowledge, views, perspectives, doubts and ideas. Variety of presentation is injected through use of guest speakers, audiotapes, videotapes, and role play. External materials encourage communication amongst participants, and provide an opportunity for self-reflection, as well as an opportunity to exchange ideas with tutors and fellow participants. In this way it is anticipated that participating teachers will be expanding their professional networks at the same time that they are increasing their knowledge of strategies that can facilitate gender equity in mathematics and science education and their capacity to generate such strategies.

Whatever their mode of study, participants are asked to complete and share with fellow participants, on a regular basis, a "process commentary." This describes their overall thoughts about their work, referring to any problems or difficulties they have encountered, and highlighting any insights they have gained. These "process commentaries" thus provide a source for ongoing, formative evaluation of the unit.

CONTENT OF THE INTRODUCTORY UNIT

The content of the unit is organized to follow approximately the classic progression from more concrete to more abstract, beginning with essentially descriptive material and moving through explanations, application and analysis to reflection, synthesis, evaluation, and generation of personal initiatives. The content is presented in three modules as follows, with an assessment exercise consolidating the outcomes of each module.

Module 1: Communication and Perceptions

This module has two major purposes. One purpose pertains to the unit's processes and focuses on communication; the other pertains to the unit's content and focuses on perceptions of the relationship between gender and science and mathematics.

On completion of this module it is expected that participants will have:

1. Established effective communication with their fellow participants.
2. Developed and shared with others a statement of their personal rationale for undertaking the unit and the personal goals they expect to achieve.
3. Clarified and expressed their personal perceptions of the relationship between gender and science and mathematics.
4. Administered the "Draw a Scientist Test" and analysed its effectiveness as a vehicle for eliciting and interpreting the image of science held by others.

Early activities involve the sharing of personal background information and lists of potential resource people, material or facilities relevant to the unit, and the articulation and sharing of personal rationales, goals, and perceptions. As many of the participants are teachers in situations where it may be important to know others' (e.g., students', peers') perceptions of science, the unit presents a number of ways of eliciting these perceptions, including various forms of questionnaire or interview (e.g., Weinreich-Haste, 1979). It is noted that another quite simple and enjoyable way to assess some aspects of others' images of science is to ask them to DRAW a scientist. Thus, for their first assignment, participants are asked to administer and analyse the "Draw a Scientist Test" (DAST) (Kahle, 1989). The readings at this stage focus on discussion of the image of science (e.g., Easlea, 1986; Kelly, 1981) and on a framework for conceptualizing the relationship between gender and science and mathematics.

The framework suggested is shown in Figure 1. It is adapted from the one developed by participants at the first international GASAT Conference held in 1981. The original framework attempted to show the dependence of girls' science and technology education on aspects of the education system, the practice of science and technology, and the operation of sex-role stereotypes in society (Raat, Harding & Mottier, 1982, p.64). For the purposes of this unit it was adapted to illustrate the relationship between gender and science and mathematics in terms of three overlapping circles, represented by:

1. Society's expectations of males and females.
2. The philosophy, aims, and organization of education.
3. Science and mathematics in practice.

The segments formed by the overlapping circles model the way in which the three initial inputs interact, with segment (4) representing the image of science and mathematics, segment (5) sex-differentiation in education, segment (6) science and mathematics curricula, and the central combined segment (7) modeling the diverse and complex influences on the relationship between gender and science and mathematics.

Participants are encouraged to use the framework to assist them in interpreting the analysis of their DAST. With reference at least to segments (1), (2), and (4), they are expected to provide examples of the ways in which messages from the wider society about the practice of science and about appropriate roles and behaviours for males and females appear to have influenced their DAST findings. In completing their analysis they are asked to provide: (a) background information on the group to whom they administered the DAST; (b) a description of the administration; (c) the DAST results of their group; (d) a discussion of

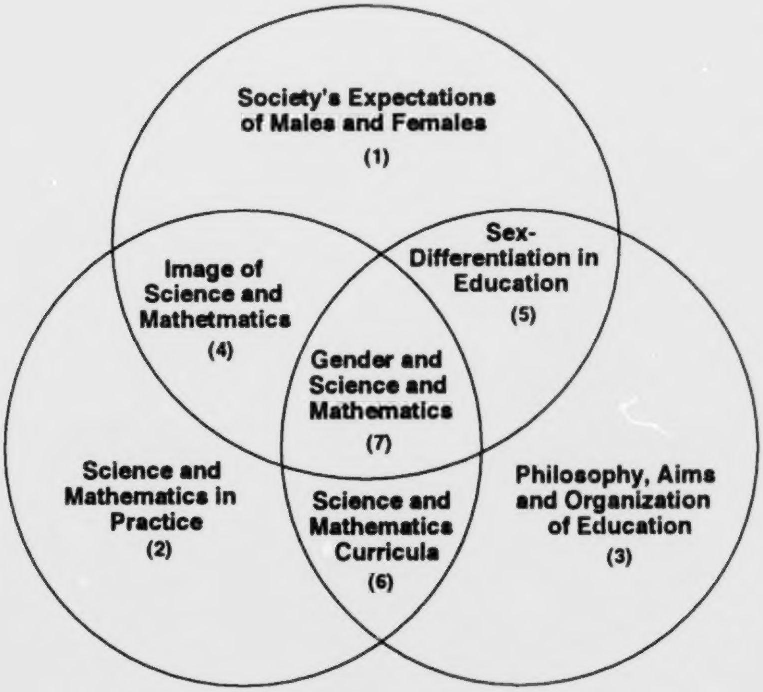

Society's Expectations of Males and Females
(1)
Sex-Differentiation in Education
(5)
Image of Science and Mathetmatics
(4)
Gender and Science and Mathematics
(7)
Science and Mathematics in Practice
(2)
Science and Mathematics Curricula
(6)
Philosophy, Aims and Organization of Education
(3)

Figure 1. A View of the Relationship Between Gender, Science and Mathematics

their group's results in terms of the background characteristics of the group and the likely influences on the "image" of scientists or mathematicians, with reference to at least the readings covered in this module; (e) a thoughtful and creative comparison of their DAST results with those of fellow students, again, if appropriate, with reference to the readings; (f) comments on the implications of their findings for their own practice; (g) comments on the effectiveness of the DAST—limits, possibilities, advantages, drawbacks.

Participants in the unit invariably enjoy carrying out this assignment. Many are surprised at how much they learn about the perceptions of the group, which they use for the DAST, and some attempt to probe these perceptions in greater depth through discussion and interview. Most are amazed at how strongly the masculine image of science continues to predominate, despite at least a decade of work attempting to project a more human, inclusive image.

Module 2: Research Findings, Interpretations and Explanations

From their work to this point, participants usually begin to realize that the whole area of gender issues and gender differences in mathematics and science is not quite as clear-cut as many people think and that different situations, points in history, cultures, societies, and educational approaches appear to produce quite different results.

The material covered in this second module reminds participants that although there may be at least a modicum of agreement about what the "real" gender issues and gender differences are, there is considerable debate about the explanations for those issues and differences. The purposes of this module are to alert participants to some of the research literature and debate about these matters and to encourage them to apply this knowledge to gender issues that they identify as affecting the teaching and learning of science and mathematics in their own setting.

After completing the module it is anticipated that they will be able to:

1. Demonstrate knowledge of research findings on sex differences in participation, performance, ability and attitude in relation to mathematics and science.

2. Identify and discuss a range of explanations for apparent science and mathematics-related sex differences.

3. Identify and discuss in detail a significant gender issue.

Discussion of research on participation in science and mathematics takes participants back to 1981, when Alison Kelly coined the term "the missing half," to describe the underparticipation of girls in science, and when, as indicated earlier, the first international gaSAT Conference was held (in Eindhoven, The Netherlands). It is noted that all of the countries participating in GASAT I shared the same problem—the low enrollment of females in science (particularly the physical sciences) and in higher-level mathematics. Material presented demonstrates to participants that since that time, at the five subsequent biennial

GASAT Conferences and in other contexts, the worldwide scale and dimensions of this problem have been revealed. It is shown that, in virtually every country for which data exist, including both developed and developing countries, sex differences in science and mathematics participation beyond the age at which the study of these subjects is compulsory are: (a) strongly in boys' favour in physics and the most demanding mathematics subjects, (b) weakly in boys' favour in chemistry, (c) non-existent or slightly in girls' favour in biology and "general" or moderately demanding mathematics subjects, and (d) strongly in girls' favour in the least demanding mathematics subjects.

The message from the research is emphasized: once they are free to choose, girls and boys participate quite differently (in both quantitative and qualitative terms) in the study of science and mathematics. Participants are asked to obtain data from a setting with which they personally are involved (e.g., class, school, district, state, etc.), and to record the ratio of males to females in various kinds of science courses and subjects. The are urged to observe and comment on the degree to which the pattern in their own setting is similar to or different from that outlined above and to suggest reasons for any differences.

The scenario then shifts to research on performance in science and mathematics. As in the case of science enrollments, it is demonstrated that there have been many studies, both large and small, and in many different countries of the world, of sex differences in science and mathematics achievement. Reference is made to the extensive studies conducted by the IEA (International Association for the Evaluation of Educational Achievement), the first in 1970-71 and the second in 1983. It is noted that these were based on multiple-choice tests administered to samples of the 10 year-old, 14 year-old and 17-18 year-old populations in 19 countries. Findings of the studies are discussed, with reference in particular to the following three general findings: First, on the tests administered in the first IEA studies, boys consistently performed better than girls in both science and mathematics in all 19 countries sampled. Second, for science the sex difference was shown to increase as students progressed through the school system, and to be greatest for physics, somewhat smaller for chemistry and smallest in biology. Third, the preliminary report of the Second International Science Study (SISS) (IEA, 1988) showed sex differences still in boys' favour, though smaller than those reported from the first IEA Study, and less consistent across countries.

The need for critical analysis, even of prestigious, large-scale studies such as those of the IEA is highlighted. It is noted, for example, that other research has struck some cautionary notes in relation to unquestioned acceptance of the findings of the IEA, for at least two reasons. First, the IEA findings were based entirely on multiple-choice test items, which some research (e.g., Murphy, 1982) has suggested favor boys, and second, the initial IEA analyses did not control for the science and mathematics background of the students in the samples. This second point provides an ideal springboard from which participants are launched into discussion of the "differential course-taking" hypothesis (Fennema & Sherman, 1977; Parker & Offer, 1987).

Participants are then asked to gather and share with others more of the data on their doorstep, this time relating to sex differences in science achievement. They document, again for various science subjects relevant to their own practical situations the achievement scores of females and males, comparing the pattern of achievement in their own situation with that of other participants, and comparing these patterns with the international research findings discussed earlier. Many comment on the valuable insights they gain from this exercise.

The unit then provides a brief introductory coverage of research on sex differences in cognitive abilities (e.g., Linn & Hyde, 1989), sex differences in attitudes towards science and mathematics (e.g., Eccles, 1989), and models for interpreting and explaining these sex differences (e.g., Parker, 1989). Participants are asked to complete the following activity, to assist them in clarifying their thoughts:

1. At your own common sense level write down what you consider to be the explanation for the relationship between gender and science and mathematics. What have been the major influences on your thinking in this regard? Are you comfortable with your personal explanation, or are there some gaps and inconsistencies in it? (If so, what are they?)

2. To what extent is it useful to categorize the various explanations for the relationship between gender and science and mathematics (e.g., as in the readings by Willis and Parker)? What, if any, is your preferred basis for categorisation? Why?

3. To what extent have the explanations for the gender/science/mathematics relationship changed throughout history? What is the significance of any such changes you have identified in your readings?

Participants then complete the second assignment, which requires them to identify and select a "gender issue" (from any level—international, national, state or local) and write a short paper on it for an audience of their own choice, preferably an audience of significance to their own professional practice. Although urged to put forward their own view-point on the issue, it is also made clear that the paper should demonstrate the ability to synthesize a variety of ideas and theories, with reference to sources as appropriate. Virtually all participants appreciate this opportunity to work through, in some depth, an issue that is personally meaningful to them. Many actually present their issues paper to its designated audience, either orally (e.g., at a parent/teacher association meeting) or in written form (e.g., in an educational journal).

Module 3: Policy and Action

The third module of the unit focuses on policy and action and has two purposes. First, it is intended to provide a systematic overview of a range of initiatives in the gender/science/ mathematics area. Second, it aims to develop skills in critical analysis and generation of such initiatives, with a view to practical application of these skills in participants' own setting.

On completion of the module it is expected that participants will be able to:

1. Describe and discuss a range of initiatives that have been undertaken to enhance gender equity in science and mathematics education, with reference to the aims, processes, and outcomes of the various initiatives.

2. Identify the characteristics of a "successful" initiative.

3. Develop and present a detailed critical evaluation of a selected initiative, with particular reference to their own future practice.

The third of the above objectives in fact foreshadows the final assignment for the unit. Participants are urged to begin thinking immediately about the initiative they plan to evaluate, discussing possibilities with colleagues and others. The initiative can be any strategy or project, developed or implemented by any person or group or organisation, to enhance gender equity in science and mathematics education. Some initiatives analysed by participants include:

1. Evenings for parents offered as part of the "Women Into Science and Engineering" program at the University of Western Australia.

2. The week-long Gender Institute offered by SMEC in 1990.

3. The Australian Science Teachers Association's policy on gender equity, as evidenced in the editorial policy of the Australian Science Teachers Journal 1987-1990.

4. The videotape produced by the "Women in Science" Project funded by Australia's national organization for scientific and industrial research.

Much of the remainder of the module is spent on the development and application of schema for analysing initiatives. First, participants carry out a descriptive classification in terms of the following six focal areas: Target Group (e.g., in-service teacher education), Person Focus (e.g., attitudes, skills and knowledge), Content Focus (e.g., careers, subject choice, self image, teaching strategies, school/classroom organisation), Methodology (e.g., video-tape), Sponsorship (e.g., a joint initiative of a teachers' association and a university department), and Range (e.g., for use nation wide).

They then take a more critical approach, analysing initiatives in terms of their: (a) rationale and general background ("why?"); (b) aims ("what?"); (c) strategies, processes or methods ("how?"); (d) theoretical position ("what evidence is there that this is the best way to go?"); (e) outcomes—both intended and unintended ("what happened?"); (f) implications ("what does this mean in relation to my own and/or others' practice?"); and (g) application ("how will I apply the knowledge I have gained from this initiative?")

A range of initiatives focusing on policy, curriculum, and teaching/learning environments is presented to participants for analysis. Materials used are drawn from projects conducted in many different parts of the world and include videos (e.g., Rennie & Yeo, 1991), audiotapes (e.g., of practitioners describing an initiative they have taken), written accounts of the implementation of an initiative (e.g., MacDonald, 1985; Smail, 1987), and policy documents (e.g., the Australian Science Teachers' Association policy statement on girls and women in science education). Participants are encouraged to begin drawing up a list of characteristics of a "successful" initiative, in other words a personal list of criteria for evaluating initiatives.

Of particular interest to most participants are materials that focus on the teaching/learning environment. Although many participants have heard of the research demonstrating sex bias (in males favour) in teacher-pupil interaction, they are unaware of the dimensions of the problem. The latter are brought into sharp focus by reference to Kelly's meta-analysis of 81 studies of teacher-pupil interaction. Participants learn from Kelly (1988) that it is now "beyond dispute that girls receive less of the teacher's attention in class, and that this is true across a wide range of different conditions". These conditions encompass all age-groups, all subjects in the curriculum, both male and female teachers, both pupil-initiated and teacher-initiated interaction and all major categories of classroom interaction (e.g., behavioural criticism, instructional contacts, high-level questions, academic criticism and praise). It is emphasised that Kelly's analysis also demonstrates that science is one of the areas in which girls are particularly under-involved in lessons.

Some participants, in an attempt to establish equitable patterns of interaction with their students, arrange for their lessons to be observed, taped or even videotaped, in order to obtain another perspective on their typical pattern, with a view to modifying it as appropriate.

Another aspect of school and classroom environment that interests participants considerably is the "co-ed/single-sex" debate. They find, from a variety of sources associated with this unit, that this is indeed a "gender issue" and one that surfaces quite emotively at times! Readings such as Sampson (1989), Byrne and Hazel (1989) and Carpenter (1985), demonstrate that each of coeducation and single-sex schooling is seen by its proponents as a strategy for improving girls' education. Participants are asked to evaluate the evidence for and against these two modes of organization, and to determine the extent to which the use of single-sex grouping can be justified as an "initiative" to increase gender equity in mathematics and science.

As a practice run for Assignment 3, participants are urged to analyse the initiative described by Rowe (1990) involving single sex mathematics classes, using the descriptive classification and the approach to analysis developed earlier in Module 3, together with the list of characteristics of a successful initiative which they have been progressively adding to throughout Module 3. They then go on to complete the third assignment, and, using these same analytical tools, complete a written, critical evaluation of an initiative of their own choice. Most find this final assignment very challenging, but also very valuable in terms of its relatively structured approach to the analysis of practical initiatives. Participants rise to the challenge of the third assignment to varying degrees. Some of the best work demonstrates an outstanding capacity to integrate theory and practice in the completion of an analytical task.

FEEDBACK AND FURTHER DEVELOPMENT

The introductory gender issues unit attracted a total of 55 participants during 1991-92. The participants varied in age, experience, and ethnicity and have been spread geographically throughout Australia and overseas locations. Nearly all provided regular formative feedback on the unit through the process commentaries referred to earlier in this paper and completed an end-of-unit evaluation questionnaire focusing on both content and organizational aspects of the unit, particularly in terms of participants' achievement of their personal goals. Of the participants to date, all except one (a person in a relatively remote overseas location) have been generous in their praise of the unit's structure, content, and teaching/assessment strategies. The following comments are typical of those made:

> I have found this unit to provide exactly what I had hoped to achieve with regard to information and ideas.
>
> I have found all of the readings provided to be both pertinent and informative. They have led on to other materials which have been of equal interest. The tasks assigned have been well focused and have helped to maintain a high level of interest on my part.
>
> I feel that I have achieved my goals that I set at the start of the unit. However, many will be ongoing and do not end with this unit. I still intend to develop more strategies and encourage girls to study science.
>
> I have become more aware of how gender differences occur and can apply this to my school. I have also tried some strategies to overcome some of these differences. I am still working on goal no. 3 (to encourage other staff to use these strategies).
>
> I have gained more ideas for strategies and assessment (as well as career advancement), and a much clearer direction and understanding of aims concerning interests and aspirations.
>
> I am satisfied that I am on the road to achieving my goals. I have begun to implement a gender-inclusive approach to our science curriculum and to use, or at least try to use, gender-inclusive teaching strategies. I involve my colleagues in both aspects as much as possible and slowly some things are happening that were not prior to my involvement in this study.

> I found this unit more interesting than I had expected. I was one of those who thought that gender differences "didn't happen here". Activities such as the DAST made the unit interesting. I found much of the unit applicable to the teaching situation. Would recommend this unit.

Not surprisingly, work on the doctoral-level unit was inspired by such positive feedback on the introductory unit. The target group for the doctoral unit, while sharing many of the characteristics of the group for the introductory unit, was known to have a much greater need for a more theoretically based approach, focusing in depth on specific areas relevant to participants' research interests.

The design challenge for the doctoral unit was to retain the obviously successful features of the introductory unit, such as the collegial approach, the relevance to current practice, the focus on personal goals, and the exploration of personal perceptions, while at the same time ensuring a rigorous treatment of relevant theory. An important aspect of the unit is its capacity to integrate participants into the international community of scholars working in the area of gender and science. For this reason, the texts and readings suggested for the doctoral unit, while retaining to some extent a practical emphasis, have a strong international flavor.

In its pilot version, which appears at present to be well accepted, the doctoral unit follows a "core-and-options" design. All participants are undertaking a core module exploring the theoretical and practical ramifications of the concept of gender-inclusiveness. They will then go on to complete two optional modules, which can be tailored to their personal research interests (e.g., gender and science in developing countries, or the feminist critique of science, or research on women scientists). The assessment task for at least one of the optional modules requires participants to develop a proposal for an initiative in the area of gender and science, explaining in detail the theoretical rationale for their project, as well as the procedures to be followed in its implementation and evaluation. It is anticipated that this approach will enhance further the gains in terms of knowledge and skills that were made by participants in the introductory unit.

CONCLUDING COMMENTS

The program described in this chapter appears to have been successful in achieving its aim of enhancing science teachers' knowledge, skills, and understandings in relation to the significance of gender in their professional practice. It can be seen as exemplary in a number of ways. First, although many programs for both initial and continuing science teacher education include some reference to gender issues, there are none on record that address the issues systematically, realistically, and thoroughly, from a strong international research base, as this program does. Second, the style of delivery of this program itself exemplifies a gender-inclusive approach, with its emphasis on personal relevance, sharing, collaboration, networking, and "the three C's of care, concern and connection" (Martin, 1982). Third, the program acknowledges and caters to the needs of teachers as professionals; it helps them to make sense of their own professional practice, to perhaps play leading roles in helping others in this regard, and to expand their personal professional networks. Fourth, and importantly in the context of teachers' needs for recognition and reward in relation to professional development, the program is designed so that it can be undertaken in a number of different study modes, linked to a variety of forms of interconnected credit.

Perhaps one of the participants should be allowed to contribute the last words to this chapter:

> This unit has opened a Pandora's Box for me. I don't understand how we can be let loose on students in our ignorance. This is the kind of relevant stuff I enjoy.

REFERENCES

American Association of University Women (AAUW). (1992). *How schools shortchange girls*. (Commissioned report prepared by the Wellesley College Center for Research on Women). Washington, DC: AAUW Educational Foundation/National Education Association.

Australia. Department of Employment, Education and Training (1989). *Discipline review of teacher education in mathematics and science*. Canberra: AGPS.

Bowles, G., & Duelli Klein, R. (Eds.) (1983). *Theories of women's studies*. London: Routledge and Kegan Paul.

Byrne, E., & Hazel, E. (1989). *Single sex vs coeducation*. Discussion Paper No. 6. Women in Science and Technology in Australia (WISTA) Project.

Carpenter, P. (1985). Single-sex schooling and girls' academic achievements. *Australian and New Zealand Journal of Sociology, 21*(3), 456-473.

Clements, M. A. (1989). *Mathematics for the minority*. Geelong: Deakin University Press.

Easlea, B. (1986). The masculine image of science with special reference to physics. In J. Harding (Ed.), *Perspectives on gender and science*. London: The Falmer Press.

Eccles, J. (1989). Bringing young women into math and science. In M. Crawford, & M. Gentry (Eds.), *Gender and thought: Psychological perspective*. New York: Springer-Verlag.

Fennema, E., & Sherman, J. (1977). Sex related differences in mathematics achievement, spatial visualization and affective factors. *American Educational Research Journal, 14*, 51-71.

Fraser, B. J., & Giddings, G. J. (Eds.) (1987). *Gender issues in science education*. Perth: Curtin University of Technology.

Hunt, F. (Ed.) (1987). *Lessons for life: The schooling of girls and women, 1850-1950*. Oxford: Blackwell.

IEA—International Assessment for the Evaluation of Educational Achievement (1988). *Science achievement in seventeen countries: A preliminary report*. Oxford: Pergamon.

Kahle, J. B. (1989). Images of scientists: Gender issues in science classrooms. *What Research Says to the Science and Mathematics Teacher*. No. 4. Curtin University of Technology: Key Centre for School Science and Mathematics.

Kelly, A. (Ed.). (1981). *The missing half*. Manchester: Manchester University Press.

Kelly, A. (1988). Gender differences in teacher-pupil interactions: A meta-analytic review. *Research in Education, 39*, 1-23.

Laird, S. (1988). Reforming 'women's true profession': A case for 'feminist pedagogy' in teacher education? *Harvard Educational Review, 58*(4).

Leder, G. C., & Sampson, S. N. (Eds.). (1989). *Educating girls*. Sydney: Allen and Unwin.

Linn, M. C., & Hyde, J. S. (1989). Gender, mathematics and science. *Educational Researcher, 18*(8), 17-19, 22-27.

MacDonald, J. (1985). Expanding your horizons in science and mathematics. In J. Craig and J. Harding (Eds.), *Contributions to the third GASAT conference*. London: Kings College Centre for Educational Studies.

Martin, J. P. (1982). Excluding women from the educational realm. *Harvard Educational Review, 52*(2), 408.

Murphy, R. J. L. (1982). Sex differences in objective test performance. *British Journal of Educational Psychology, 52*, 213-219.

Parker, L. H. (1989). Science for all? *Australian Science Teachers' Journal, 30*(1), 21-28.

Parker, L. H. (1991). Gender issues in science and mathematics education: Materials for use in the professional development of teachers. In L. J. Rennie, L. H. Parker, & G. M. Hildebrand (Eds.), *Action for equity: The second decade*. Perth: National Key Centre for School Science and Mathematics.

Parker, L. H., & Hillman, W. (1990). Womens studies. In C.J. Marsh (Ed.), *Teaching social studies*. Sydney: Prentice Hall, 1990.

Parker, L. H., & Offer, J. A. (1987). School science achievement: Conditions for equality. *International Journal of Science Education, 9*(3), 263-269.

Parker, L. H., Rennie, L. J., & Fraser B. J. (Eds.) (1992, in preparation). *Gender, science and mathematics: Shortening the shadow*.

Raat, J. H., Harding, J., & Mottier, I. (Eds.). (1982). *Congressbook GASAT conference 1981*. Eindhoven University of Technology.

Rennie, L. J., Parker, L. H., & Hildebrand, G. M. (Eds.) (1991). *Action for equity: The second decade*. Perth: National Key Centre for School Science and Mathematics.

Rennie, L. J., & Yeo, S. (Producers). (1991). *Learning science: Promoting a gender-inclusive science curriculum*. Videotape. Perth: National Key Centre for School Science and Mathematics.

Rowe, K. (1990). What are the benefits of single-sex maths classes? *SET, No. 1*, Item 9.

Sampson, S. (1989). Are boys a barrier for girls in science? In G.C. Leder, & S. Sampson (Eds.), *Educating girls*. Sydney: Allen and Unwin.

Smail, B. (1987). Encouraging girls to give physics a second chance. In J. Craig, & J. Harding (Eds.), *Contributions to the third GASAT conference*. London: Kings College Centre for Educational Studies.

Treagust, D. F., & Rennie, L. J. (Eds.) (1989). Gender-inclusive science and technology education [Special issue]. *Australian Science Teachers Journal, 35* (3).

Tyack, D., & Hansot, E. (1988). Silence and policy talk: Historical puzzles about gender and science. *Educational Researcher, 17*(3), 33-41.

Weinreich-Haste, H. (1979). What sex is science? In O. Hartnett, G. Boden & M. Fuller (Eds.), *Sex role stereotyping*. London: Tavistock.

Chapter 13

Creating Cultures for Change in Mathematics and Science Teaching

Nancy T. Davis
Kenneth L. Shaw
B. Jo McCarty

The schools of today were formed in the industrial age, and much of the tradition is based on meeting the needs of society at that time. Society has changed, however, and the schools have not kept up. There is wide agreement that schools must meet new demands and challenges. As change occurs in our schools, there is a genuine need to better understand the processes of change and how individuals become enabled to change. This chapter reports research that is part of a programmatic effort to develop understanding of teacher change and provides insights into creating cultures for change.

PERSPECTIVES ON CHANGE

House (cited in Rossman, Corbett, & Firestone, 1988) described three perspectives of change: the technical, the political, and the cultural. As most innovators have been operating from an objectivist view of reality, the predominant focus of most change research has been on the technical and political perspectives of change. These views of change are seen from an authoritarian vantage point as researchers describe teachers reactions to specific changes in practice proposed from outside the culture (Richardson, 1990). Our research, however, is grounded in constructivism and is intensely concerned with individuals' interpretations of their experiences. Hence, this research is focused on the cultural aspects of change. The definition of culture used in this study relies heavily on the definition purposed by Rossman et al. (1988):

> Culture describes the way things are; it interprets events, behaviors, words, and acts—and gives them meaning. . . . Culture also prescribes the way people should act; it normatively regulates appropriate and acceptable behaviors in given situations. Thus culture defines what is true and good. (p. 5)

Rossman et al. (1988) explicated three cultural change processes: (a) evolutionary, which occurs over long periods of time as the culture acquires new content such as differing participants; (b) additive, when beliefs are modified quite suddenly and spread to entire belief systems; and (c) transformational, when outside influences seek to change the belief systems radically. They describe the differences between these categories of changes.

> Processes of cultural change may be evolutionary when new norms, beliefs, and values are introduced and discarded over time; they may be additive when new beliefs reverberate through and change a culture; and they may be transformative when cultural norms are challenged severely. (pp. 14-15)

It is our fundamental belief that for schools to function effectively in our rapidly changing world, radical changes are necessary. In our research project, we sought to initially have transformational change as we consciously attempted to establish new cultural norms based on a constructivist paradigm. When the new culture was established we expected there to be additive changes as teachers continued to reflect on their own practices and as the beliefs and ideas of teachers spread to their individual school cultures.

Rossman et al. (1988) assert that transformational change is difficult to effect. However, if we use the perspective of scientific revolution, as proposed by Kuhn (1970), and apply that to the cultural change process (Davis, McCarty, Shaw & Sidani-Tabbaa, in press), it then becomes more feasible. By closely attending to the individuals involved in the project and to their beliefs and values, by attempting to develop an understanding of how they are making sense of their world, and by proposing an alternative way of making sense, we believe transformational changes can occur.

After the failure of decades of mandated, technical reforms, more and more professional educators are looking for alternatives. To make significant changes in schools requires more than the passing of legislation or curriculum mandates, it requires a shift in how teachers think about teaching and learning. Assisting teachers to rethink their beliefs about teaching and learning is an intensive process that includes a close examination of and involvement in the context within which the teachers operate. The cultural perspective includes examination of the beliefs, norms, and values of the participants of the culture.

Strategies that facilitate the establishment of a culture need to be considered when seeking transformational change. Rossman et al. (1988) delineated three categories of influence strategies that occur in the literature:

- attending to desired values and deliberate role modeling
- interpreting the symbolic elements of organizations, that is, stories, myths, mottos, and symbols
- shaping organizational systems to express cultural assumptions. (p. 16)

Our research team attended to the desired values of the teachers by asking them to establish a consensual vision of what they wanted teaching and learning to be (e.g. Shaw, Davis, McCarty, & Sidani-Tabbaa, 1990). As the teachers verbalized their vision, they were able to express their beliefs and values. By returning to the vision periodically, the research team could retain awareness of the evolution of teacher thinking as it occurred.

As researchers, we consistently considered how our roles might be interpreted by the teachers. Because of their past experiences with educational research and researchers, the teachers initially thought that we were coming to the schools with new techniques for them to implement. They believed that as university researchers we knew more and better than they, and that their roles would be to implement our plans. While the initial meetings with the teachers were structured by the research team, we had as a goal teacher direction and were soon able to place the responsibility for formulating and structuring meetings with the teachers. We deliberately tried to model collaboration and negotiation on an equal basis. One of our roles in the project has been as co-learners with the teachers as we model collaboration, which we want the teachers to apply in their classrooms.

A primary focus of our research program is to develop an understanding of how teachers make meaning of their teaching. We have asked the teachers to examine their own metaphors for teaching, myths underlying the school culture, and meanings associated with language. Shaw (1992) is currently conducting further research into myths of schools as perceived by differing members of the culture, administrators, teachers, and students. Davis (e. g., Davis, McCarty, Shaw, & Sidani-Tabbaa, 1991; Davis, Shaw, & McCarty, 1992) is focusing on symbols and language in a study of semiotics as related to developing shared understanding within a culture. McCarty (e.g., Davis, McCarty, Shaw, & Sidani-Tabbaa, 1992; McCarty & Alkove, 1991) is investigating the conditions for establishing a culture for change.

In establishing a new culture to facilitate transformational change, the cultural assumptions we sought to create are reflected in our beliefs about education and the nature of change. Basic tenets underlying the research project were: (a) the unique individual person of the teacher is central to the education process; (b) teachers have the necessary knowledge and skills to best handle the problems and issues in the schools and bring about school restructuring; (c) collaboration, mutual support, and learning among teachers is a vital component of teacher empowerment; and (d) lasting changes must occur within the individual as a result of conscious choice.

This paper will explain the process of establishing a culture in which change is facilitated and will discuss the evolution of the project. To explicate our discussion on culture and teacher change, we will refer to our research project, The Enhancement of Mathematics and Science Teaching (EMST) Project. The EMST Project is a collaborative effort between county administrators, principals, teachers, and researchers to improve the instruction of mathematics and science throughout Bay County, Florida. The goals of the project include having teachers focus on learning mathematics and science with understanding, increasing communication and support between teachers of science and mathematics, increasing communication and support between teachers of differing grade levels, assisting teachers in developing and implementing a vision of teaching mathematics and science, and providing teachers with an opportunity to develop professional empowerment.

THE EMST PROJECT

Year One—Getting Established

The EMST Project began in Bay County, Florida, in September 1989. Researchers discussed with district administrators the feasibility of establishing a "family of schools" in Bay County. A family is comprised of teachers from an elementary school, middle school, and high school. The family of schools are selected so that students entering the elementary school would naturally progress into the middle school and then into the high school. As we were seeking to establish a new culture, we wanted to collaborate across the established cultural boundaries of schools. Drawing students from the same population would allow teachers to discuss common problems; teachers could then address mathematics and science problems across grade levels. The district administrators were very supportive of the family concept and recommended Springfield Elementary School, Everitt Middle School, and Rutherford High School to be the family of schools. In addition to granting their verbal support, they offered the participating teachers three days to be used to collaborate on improving mathematics and science instruction.

In early October, the researchers made appointments with the principals in the three schools and shared the design and purpose of the project. Without exception, the principals were excited about the project and agreed to have their school become part of the project. We asked the principals for their suggestions of teachers who would be willing to spend time in the project and who had a commitment to mathematics and science education. Two coordinating teachers were selected from each school. In both the middle school and high school, one mathematics teacher and one science teacher were selected. These six teachers made up the original family. We initiated a meeting with these teachers and explained the purpose of the project and asked them if they would be willing to participate. The teachers understood that their participation was voluntary, and they could withdraw if they chose. One of the initial teachers identified by her principal did withdraw because she felt that the time commitment was beyond what she could make.

The teachers in the original family included: Dan, a veteran high school biology teacher with 21 years teaching experience, who was also enrolled in graduate courses in science education; Michael, a beginning high school mathematics teacher; Cathy, a middle school mathematics, science, and reading teacher, in her fourth year of teaching; Mary Ann, a middle school mathematics teacher with 5 years experience; Jean, a fourth grade teacher with 16 years teaching experience; and Irene, a kindergarten teacher with 7 years experience who joined the project late, after the initial teacher withdrew from the project.

Once the teachers and principals had agreed to participate, an initial meeting was set to discuss teaching and learning. At this meeting an alternative view of learning, constructivism, was discussed with the teachers. Then the task was to have teachers establish a vision of what they would like to see in their instruction and in student learning. The teachers were encouraged not to consider any constraints and only to think of the ideal setting when formulating the components of the vision. The teachers, researchers, and principals met in small groups for nearly two hours negotiating the components of a vision. Teachers shared their components and as a group modified, deleted, and added new components to their vision, until they reached a consensus of 15 components. This vision has been used by teachers as a framework to compare their progress in establishing an ideal classroom. The vision is revisited periodically for revision and renewal.

The family met together two or three times a month to discuss their progress. The meeting places rotated among the teachers' classrooms. The host teacher facilitated the meeting. Initially, the researchers set the agenda, but as the teachers became more involved in the project, they began setting their own agendas. In the family meetings the teachers reflected on teaching and learning of mathematics and science. They sought alternative approaches to utilize and discussed their implementation of new strategies in subsequent meetings. As a result of the family meetings, teachers made notable and worthwhile changes in their own classrooms. These changes are discussed in a later section.

In this first phase of the project, the research team was intensely involved with the teachers. Case studies of each of the teachers were written based on classroom observations, interviews, meeting transcriptions, videotapes, journals, and written responses from the teachers (Shaw et al., 1990). Because we sought to develop an understanding of the teachers' perspectives, the case studies were shared with the teachers and their reactions were included. These case studies provided the foundation for reflection on changes made, and development of a theoretical model of change.

Two teachers were initially selected from each school with the intent that after two years, they would have established model classrooms so other teachers could observe their teaching and gain images of alternative teaching strategies. It was proposed at this point that other teachers would be invited within a school to join the project with the original teachers in the family assisting the new teachers in the family. After time, these new teachers would help other teachers and as this processed continued, a model school would be established. Teachers from other schools would then begin to participate to develop a new family of model schools.

This intended model of growth within Bay County did not succeed for several reasons. First, interest within schools and from other schools began very early in the project. For example, the Bay County Science Council invited the Bay County Mathematics Council to have a joint meeting where teachers from the family would share what they had learned about teaching and learning and what they were trying in their classrooms. As a result of this meeting, many teachers became interested in the project and wanted to know more about it and how they could participate. We reconsidered our growth plan and decided that natural growth from interested teachers would be more effective and beneficial. Late in the spring of 1990, a second family was formed utilizing a similar structure as the first family.

During the summer of 1990, twelve teachers from two families met together to consider curricula changes they could initiate. The teachers received stipends provided by a Florida Department of Education grant for two weeks of the summer. By the fall these teachers had designed an environmental project that involved a combined effort of the students of all of the teachers. Elementary students placed coffee filters in their home air conditioner units and returned them after two weeks. These filters were collected and weighed by high school students to determine weight differences and to analyze the pollutants found on the filters. The middle school students mapped filter locations and reported the findings. The teachers constructed a display that presented the data on a map of Bay County. Near the paper mill and county trash incinerator significantly more pollutants were collected. The display was exhibited in the Panama City Mall during National Education Week. Many problems arose during the collection and analysis of the coffee filters and teachers realized a need for further content knowledge and subsequently some of the teachers sought ways to obtain that knowledge through continued studies.

Year Two—Evolution and Expansion

The Bay County District Office personnel were encouraged by the progress that the teachers involved in the EMST project were making. They decided to continue their support by increasing the teacher release days from 18 to 48 days. Part of those days was utilized by Family One members to mentor newly forming families. In the next few months three additional families were formed and growth within the original family was increasing. A second problem that was encountered was the increasing number of teachers within a family. Teachers realized they could not voice their opinions as often in a larger group. They expressed the desire to remain in groups of six to eight. A third problem arose as we hypothesized that we would soon be facing 15 to 20 families. A new growth model was needed.

We requested from the county office a list of schools and their feeder schools. We made a decision to only have three families that would be based out of the three high schools. Small working groups would be created within each family and would still represent teachers from elementary, middle, and high schools. When a teacher calls and expresses an interest, we could use this model to suggest they go to a particular working group in a particular family. Once a working group became too large, the teachers would divide into two working groups. This way teachers could continue to work together in small groups and have an active voice in their discussions. However, by the end of the second year the teachers expressed a desire to have the sub-groups rejoin the larger family structure. They felt that communication with the other family members was lost in the smaller groups. Again, we adjusted our plans to meet the needs of the teachers involved in the project.

Communication between all participants and the school administration remained a high priority. But as the meetings began to multiply, writing the letters following each meeting became too consuming of both time and resources. So, in the second year a monthly newsletter was created to be disseminated to teachers, researchers, and administrators, to keep them abreast of events within each family and to provide a forum for the different voices. Teachers and administrators as well as the research team, have submitted articles for the newsletter. The newsletter also is useful in disseminating information to prospective family members as well as other interested persons.

By the end of the second year over 40 teachers were involved in the three families. The Bay County District Office continued its support of the project and committed 100 teacher leave days and $1500 for teacher travel for the following year.

Year Three—Further Growth and New Directions

Over the summer of the second year, the research team received additional funding from Title II to support and expand the EMST Project. The grant was a joint proposal between Gulf Coast Community College and Florida State University. The Community College designed high tech laboratories for use by family teachers and their students. Faculty from the community college also attended family meetings and responded to individual teacher's requests for information or assistance. As the community college joined in the project, the educational strand was completed from kindergarten through the university. The addition of content experts, who have a deep commitment to assisting teachers, provided added support to the families.

Research team members attend each family meeting to provide alternatives, to collect data, and to facilitate family interactions. Periodically, individual families may need to meet to re-establish their vision and direction. Members of the research team may detect problems in direction, or the family members may request a meeting to re-focus. Utilizing the leave days provided by the county, a whole family meets to discuss problems and possible solutions. On these days families meet on the university campus, which facilitates interactions. Teachers involved in the families are becoming much more proactive in establishing direction and needs for their families.

Currently, more than 75 teachers are involved in the EMST project. Discussions are occurring with surrounding school districts about the possibility of establishing families of schools in their districts.

CHANGES

Changes in Teachers

The changes teachers made will be reported in this section, which is focused primarily on the six original family members because of the extensive data collected from them. Other families reported their changes through questionnaires and interviews with the research team.

In discussing cultural change, we must address the changes people have made within the school culture. Change can occur at several levels ranging from overt and observable changes to cognitive changes in beliefs. The changes addressed in this section of the paper are the substantial changes that occurred as teachers reflected on and modified their beliefs concerning teaching and learning.

By bringing alternative paradigms to conscious awareness, teachers began examining their long-held traditional beliefs about education and realized they could choose to alter their thinking. Questioning and reflection have led to teachers' inward commitment to improving student learning. Teachers have become more reflective and empowered as they make decisions and take responsibility for their own learning and changes. As they considered teaching and learning from a constructivist perspective, the teachers were able to redefine their roles, the students' roles and to reconceptualize the constraints which hindered achieving their vision.

Redefining Roles

As the teachers' views of knowledge, teaching, and learning changed, they developed new roles and attached new meanings to established roles. Instead of being authoritarians and sources of knowledge, the teachers' roles changed to facilitators seeking to design a learning environment in which students would feel safe enough to take cognitive risks. Focusing on constructivism and its attention to individual's perspectives, the teachers were able to change their classrooms from a teacher-directed model to one that was more student-centered. Jean mentioned that her ability to accept students' perspectives and unique constructions was enhanced as her view of knowledge changed from an absolute knowledge base to knowledge constructed by humans using their personal experiences.

> I used to say, "Pick out what you think is important" and then if it wasn't what I thought was important they (students) got a bad grade.... Now, if I look at the child and they've put forth the effort to make personal meaning out of it then they're fine.

Thus, the teacher's main focus has changed from a concern to cover content to a concern with student learning with understanding. Jean explained, "I am giving my students more opportunities to question and explore alternative answers.... I have kids explain their answers and I no longer accept one word answers. This way I can better assess my students' understanding." Teachers want their students "to figure things out for themselves" and are emphasizing the importance of the problem-solving process instead of just reaching right answers. When trying to emphasize student learning with understanding, teachers found that de-emphasizing the importance of correct answers and grades promoted a non-competitive environment and helped engage more students in the learning and socialization process.

As they put the role of facilitator into effect, the teachers created a different environment in their classrooms. Just as the teachers were provided with a safe environment by participating in the EMST Project, the teachers established a similar, non-threatening environment in their own classrooms. During EMST meetings, teachers shared successes and failures, and examined and negotiated alternative teaching methods such as cooperative learning. Utilizing cooperative learning, the teachers began redefining their new roles and allowed students to become "risk takers." The teachers facilitated the creation of a safe environment by emphasizing with the students "helping" and acting as "support" for one another. In helping students to learn to work in groups, Jean used modeling techniques to assist her students to develop images of their roles. She acted as a student in a group as she illustrated to students concepts of sharing, negotiation, collaboration, disagreeing, and helping. The teacher as co-learner rather than teacher as source of knowledge was another role change the teachers made. Mary Ann exemplified this change;

> I think the reason why my classroom has changed is because my role has changed. Now, I am more of a questioner than a dispenser of knowledge. I ask more questions, I no longer lecture and dispense knowledge to my students but ask them questions so that they end up with more questions they have to answer.

As a result of this change in the teachers' view of knowledge and their roles as teachers, they no longer considered textbooks as "Bibles," but as available resources for both teachers and students. Cathy discussed her role as learner;

> I also try to think more for myself, I think I even understand how I think better. From this viewpoint, constructivism has helped me understand how I learn myself.... I put myself more with the students and tell them that we're in this together, struggling to learn. And now I tell my kids that there's a lot of things I don't know, so we're going to have to learn together; while before I thought you [the teacher] had to know it all.

The teachers' roles also changed as they developed into reflective practitioners. They became active learners and researchers, questioning everything they did rather than passively accepting traditional norms. Jean remarked, "Before

EMST, I was in my nice little traditional classroom, all happy and satisfied. Now, I am trying things and wondering where I am half the time, looking at changes, spending more time looking at what I do."

As a result of examining their beliefs about knowledge, teaching, and learning, the teachers have developed increased self-awareness and redefined teaching. The teachers have become empowered as they develop confidence and a sense of self-worth that has resulted in increased professionalism.

This feeling of professionalism was evident as the teachers, more cognizant of students' needs, became more actively involved in decision-making. One example was provided by Mary Ann who described a special group of students in her eighth grade algebra class, "They don't like school or math. They're very negative with low self-esteem and motivation." With this particular group, Mary Ann decided to change her teacher role to relate better to the students', to even "act silly" and "do funny things" to encourage students to respond and cooperate. As an empowered teacher, Mary Ann has shown concern for her students and has taken the initiative to adjust her teaching role to fit her students' needs.

The teachers extended feelings of professionalism to their involvement with other educational contexts. They became more active in their professional organizations, taking leadership roles and making professional presentations. They spoke up in their schools, recommending curricular changes, designing and implementing school reforms. Dan reflects on his personal empowerment;

I don't see a teacher who's empowered as necessarily being at the top of the ladder, but rather at the bottom of the ladder realizing that they can climb the ladder and beginning to climb it rather than staying at the bottom like we see so many doing, because it is safer at the bottom of the ladder as you can't fall off. But if you're empowered, you don't mind falling off because you know you have the power to climb again. A teacher with self-confidence and a good feeling about themselves can move mountains. I know that I am empowered in that I know that I can do it, that I want to do it, and that I will.

The teachers became more empowered as they took on roles of researchers in their own classrooms, questioning what works and what does not and how they can improve their teaching. After Jean implemented cooperative learning groups in her classroom she collected responses from students on how they reacted to the change in her classroom. Utilizing data from students, she was able to structure group activities to enhance student participation.

Teachers from other families also reconceptualized teaching and learning. They were asked to describe their personal changes and a summary of their responses is included (see Table 1).

The obvious change in the metaphors teachers used to describe teaching and learning reveals their reconceptualization of their roles in the classroom. Each of the noted changes shows that the teachers are taking more control of their professional practices and view teaching much more positively.

Table 1. Role Changes Reported by EMST Teachers

Teachers' report of reconceptualized roles:
From taskmaster to motivator
From rigid to flexible
From dispenser to facilitator
From telling to questioning
From subject-centered to student-centered
From teacher centered values to valuing students' opinions
From doing routines to taking risk
From not caring why to desiring to understand my motives
From tunnel vision to an unlimited vision
From taking constraints as unchallenged barriers to making it a challenge to overcome barriers
From structured to spontaneous
From dictator to coordinator
From negative to positive
From pessimistic to optimistic
From "You'll fail if you don't. . . " to "You're not allowed to fail."
From grader of papers to creator of projects and games
From "We can't do that" to "Why don't we try this?"
From stressed out to calm
From sarcastic to complimentary
From bored to interested
From failure to success
From answer-oriented to thinking-oriented
From hating math to liking it
From viewing mathematics and science as separate to connecting mathematics and science
From [students] seeing me as "mean" to seeing me as "nice"
From teacher-dependent to peer-dependent
From sitting in rows to working in groups
From failing to passing.

Reconceptualizing Constraints

During the process of becoming empowered, the teachers reconceptualized their views of constraints. They realized that constraints are personal constructions resulting from their own interpretations of experiences. This does not mean that all constraints disappear. However, by viewing them as personal constructions the teachers were able to reconsider their constraints. Several teachers illustrated this point. Dan said,

> I've learned when faced with a constraint to take a step back and question, "Is that a true constraint or is it something that I perceive as a constraint and will my changing my way of thinking make the constraint disappear?"

Referring to her own changes, Cathy added,

> I view constraints differently. Often I realize that I am the constraint, as some of the constraints I thought were there were my own constructions. I am more of a risk taker.

Jean, discussing how she reconceptualized constraints, remarked,

> Before the [EMST] Project, if I wanted to do something I usually did it, but I used the constraints when I wanted to. They were convenient and made excellent excuses for things I knew I probably ought to do, but there was this constraint. I could use it as an excuse because I didn't want to do it most of the time. . . . Now, if I think it's worth the effort, then I try to do something about it.

As the teachers realized they had choices in how they viewed constraints, they became more empowered. Michael summed up how this new feeling of empowerment helped him to arrive at his present beliefs by saying,

> I view constraints as something that I will somehow get around and overcome. I am more determined to get something done which comes with us [the EMST teachers], being more confident and empowered.

The teachers' feeling that they were important and what they think was valuable has helped them to gain confidence in themselves, to heighten a feeling of self-esteem, and to view themselves as professionals in the full sense of the word. They demonstrated their professionalism as they became more involved in their profession outside the classroom.

Changes in Students

The changes in teachers' roles have resulted in changes in students' roles. An administrator noted, "If you empower the teacher and you haven't empowered the student, then you still have not reached the ultimate goal where students take responsibility and ownership for their own learning."

Teachers believed changes in student roles resulted from the classrooms being more student-centered as they provided a more appropriate learning environment where students could be risk-takers. Consequently, students accepted the role of active learners and constructors of personal meaning. They were no longer passive receivers of knowledge. With the aid of constructivist teachers and cooperative learning, students were introduced to new definitions of "learning." Learning now implies sharing, collaborating, helping, and negotiating with others to reach better understanding through shared meaning. Jean noted, "As students collaborate and share with one another, I notice that they pick up more of what is important and learn more." In addition, as activities integrating subject areas were used, students' perceptions of mathematics and science changed. Cathy said, "Half the time they don't know if we're doing math or science or reading."

Another role change was reflected as students developed confidence and found their own voices and became teachers. Cathy described her class, "I see the students as becoming the teacher too. Like I am not the only one who teaches; we [teacher and students] all teach each other." Michael illustrated the results of this increased confidence, "Students are more able to share ideas and to accept criticism when they go to the board; they don't get as upset as they used to." Dan agreed, "Students are more comfortable with sharing and voicing their views."

Teachers have also noticed changes in students' attitudes. They are more positive toward learning mathematics and science. Cathy reported, "They are now saying, 'What are we going to **get** to do?' instead of, 'What are we going to **have** to do today?'" Another change in students is their attitudes toward others and self. Cooperative groups allowed students to learn in a social, non-competitive environment where they were learning to value and accept differences. Grades were de-emphasized and student learning with understanding was the primary concern. In these "failure-free" environments, students self-awareness was enhanced and they were more willing to share ideas with their group or the whole class. Michael summed up the changes saying,

> I see better social skills and open mindedness in students. They are more aware of other people's opinions and feelings and value them even if they don't always agree or understand them. They simply know that they have reasons for their beliefs.

A final change in students reported by the teachers was in their behavior while working in groups. Mary Ann remarked, "Kids are not as competitive and there is no cheating."

CONCLUSIONS

This project is based on the premise that radical changes in education need to occur for it to meet the needs of our changing society. Transformational change as proposed by Rossman et al. (1988) guided our thinking, as we sought to design a community of teachers who could support each other throughout the change process. In this paper we have sought to create in the reader's mind an image of change that is occurring within one project. The concept of the family of schools was presented as one possible design for a culture conducive to change. Although this design was very dependent upon the context of the educational system within which it was formed, we believe the idea of the family holds potential to be utilized in other contexts. The forming of a family across school levels allowed the teachers to create a new culture for change. The expectations and images of the school cultures within which each of the teachers operated daily could become secondary as the teachers found support from the members of their new culture. Thus, transformational change was facilitated as the teachers reconceptualized their and their students roles in teaching and learning. The teachers became empowered as they reconceptualized their views of constraints and realized that those constraints were for the most part personal constructions over which they had control.

As a result of being involved in the EMST Project, teachers are becoming more professional, wanting to know what is happening beyond their classrooms, schools, and district. They have become involved and are very active in professional organizations and meetings. Attending and presenting at professional meetings has given the teachers a broader view of education. They understand better the state and national trends and how the EMST Project is consonant with those recommendations. The teachers are feeling more like professionals and are enjoying their new roles in enhancing mathematics and science teaching in Bay County, in the State of Florida, and in our nation. They believe they are making a difference and they are!

ACKNOWLEDGMENTS

We would like to express our appreciation to the Bay County School District and to the dedicated teachers who are a part of the EMST project. Because the results of this study have been so positive we have used actual names of teachers and schools with their permission.

REFERENCES

Davis, N. T., McCarty, B. J., Shaw, K. L., & Sidani-Tabbaa, A. (1991). *Semiotics in the school culture*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL. (ERIC Documents Reproduction Service No ED 332 238)

Davis, N. T., McCarty, B. J., Shaw, K. L., & Sidani-Tabbaa, A. (in press). Transitions from objectivism to constructivism in science education. *International Journal of Science Education*.

Davis, N. T., McCarty, B. J., Shaw, K. L., & Sidani-Tabbaa, A. (1991). Culture and Teacher Change. In M. J. Brown (Ed.), *Proceedings of the Fourth Annual Conference of the Qualitative Interest Group*. (pp. 251-262). Athens, GA: University of Georgia.

Davis, N. T., Shaw, K. L., & McCarty, B. J. (1992). *Looking at communities for change*. Paper presented at the Annual Meeting of the Association of Teacher Educators, Orlando, FL.

Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press.

McCarty, B. J., & Alkove, L. D. (1991). Establishing a microculture for change within an interdisciplinary multi-grade program. *Proceedings of the Ninth Annual Nontraditional/Interdisciplinary Conference*. Virginia Beach, VA: George Mason University.

Richardson, V. (1990). Significant and worthwhile change in teaching practice. *Educational Researcher*, *19* (7), 10-18.

Rossman, G. B., Corbett, H. D., & Firestone, W. A. (1988). *Change and effectiveness in schools: A cultural perspective*. Albany, NY: State University of New York Press.

Shaw, K. L. (1992). *Understanding cultural perceptions: A referent for teacher change*. Paper presented at the Annual Meeting of the Association of Teacher Educators, Orlando, FL.

Shaw, K. L., Davis, N. T., McCarty, B. J., & Demerest, A. (1991, December). *Enhancement of mathematics and science teaching project: An executive summary (1990-1991)* (Report to the Department of Education). Tallahassee, FL: Florida State University.

Shaw, K. L., Davis, N. T., McCarty, B. J., & Sidani-Tabbaa, A. (1990, June). *The enhancement of mathematics and science teaching project* (Report to the Department of Education). Tallahassee, FL: Florida State University.

Chapter 14

A Science Inservice Program Designed for Teachers of Hearing-Impaired Children

Charles R. Barman
Jill D. Shedd

Several national surveys of science teachers indicate that little emphasis has been placed on science in the curriculum for hearing-impaired students (Lang & Propp, 1982; Moores, 1987; Sunal & Burch, 1982). These surveys have also revealed that few science teachers working with hearing-impaired students have had adequate preservice or inservice preparation in science education (Lang & Propp, 1982). Currently, as in the past, the emphasis in deaf education has been in the areas of speech, reading, grammar, and communication skills and has excluded any focus on science (Council on Education of the Deaf, 1972; Lang & Propp, 1982; Indiana License Program for Hearing-Impaired, 1990).

There seems to be no pedagogical reason for omitting science from the deaf child's curriculum. Available literature suggests that the condition of deafness poses no limitations on the cognitive capabilities of an individual (Moores, 1987). Special educators generally believe that hearing-impaired students should be provided with the same experiences offered hearing students. The following statement by Lang (1984) exemplifies this feeling: "The hearing-impaired student is as curious as the hearing student and should have experiences which permit the acquisition of knowledge, testing of hypotheses, and gradual development of reasoning."

There also appears to be a general consensus among educators that hearing-impaired students are more successful in science programs that involve "hands-on" exploratory experiences (Lang, 1984). Programs of this type provide hearing-impaired children with the concrete experiences necessary to enable them to develop science concepts. Therefore, teachers of the hearing-impaired need meaningful inservice education that will provide them with teaching strategies and materials that allow their students to be actively involved in "doing science." It was for this reason that the following inservice program was developed.

Background Information Related to the Inservice Program

The science inservice program was organized during the 1989-90 academic year. This program began in the summer of 1990 and continued through May, 1992. The overall goal of this program was to enhance the science teaching skills of teachers of the hearing-impaired in Indiana. The specific objectives of this program were to introduce K-8 teachers of the hearing-impaired to an effective way to teach activity-oriented science, to help them implement this strategy into their science instruction, and to provide them with a rationale for using this approach.

The main instructional model used in the inservice program was the learning cycle. Originating in an elementary science program called the Science Curriculum Improvement Study (SCIS Handbook, 1974), the learning cycle was modeled after Jean Piaget's theory of cognitive development (Lawson & Renner, 1975). Recently, literature suggests how this instructional model is also consistent with several other current learning theories (Barman, 1990).

The learning cycle consists of three distinct phases: (1) exploration, (2) concept introduction, and (3) concept application (See Figure 1). During the exploration phase, the teacher presents students with a problem or a task. This challenge is open-ended enough to allow students to follow a variety of exploration or investigative strategies, yet specific enough to provide some direction. The purpose of this phase is to engage students in a motivating activity that will provide a basis for the development of a specific concept and new vocabulary pertinent to the concept. This phase also provides an excellent opportunity for students to examine their personal knowledge about specific natural phenomena and for teachers to assist students in resolving discrepancies in their understanding of the natural world.

In the second phase, concept introduction, the teacher gathers information from the students about their exploration experience and uses this to introduce the main concept of the lesson and any new vocabulary related to the concept. Materials, such as textbooks, visual aids, or other written materials may be used to facilitate the concept introduction.

The final phase, concept application, is an opportunity for students to study additional examples of the main concept of the lesson or be challenged with a new task that can be solved on the basis of the previous exploration activity and concept introduction. Ideally, the additional examples of the concept or the new task will have a direct relationship to the everyday lives of the students.

Probably the most important aspect of the learning cycle that leads the authors to believe it was an acceptable model for teachers' of the hearing-impaired is its ability to enhance language development (Barman, Cohen, Furuness & Shedd, 1991). Hearing-impaired students, like other learners, need physical experiences to help them "build" visual models to represent various objects and events. Words are the abstract symbols that represent these experiences. The exploration phase of the learning cycle creates the initial physical experiences needed to begin language development. The concept introduction phase uses these experiences to introduce specific vocabulary and the concept application phase serves as a mechanism to expand and to reinforce this vocabulary.

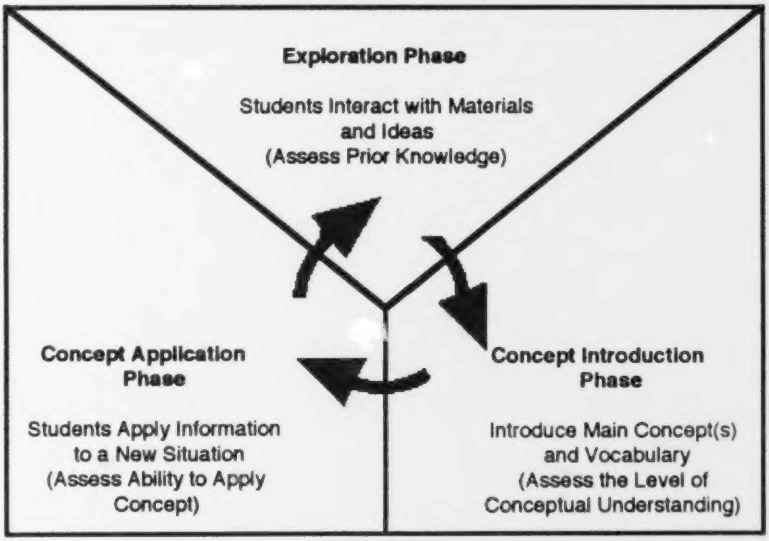

Exploration Phase
Students Interact with Materials and Ideas
(Assess Prior Knowledge)
Concept Application Phase
Students Apply Information to a New Situation
(Assess Ability to Apply Concept)
Concept Introduction Phase
Introduce Main Concept(s) and Vocabulary
(Assess the Level of Conceptual Understanding)

Figure 1. The learning cycle

The Inservice Program

The overall goal of this inservice program was to enhance the science teaching skills of K-8 teachers of the hearing-impaired in the State of Indiana. The specific objectives of this program were (a) to introduce teachers of the hearing-impaired to the learning cycle, (b) to help them implement this strategy into their classroom instruction, and (c) to provide them with a rationale for using this approach. To accomplish these objectives, the learning cycle was modeled throughout the inservice program. In effect, the learning cycle was the framework not only for lessons by the teachers but also the overall structure of the inservice program. For example, the inservice participants were introduced to the learning cycle in the following way. In the exploration phase, the teachers participated in a learning cycle lesson dealing with open and closed circuits. After they completed this lesson, they were asked to examine the outlines of two other lessons dealing with similar content. (These lessons did not follow the learning cycle.) The participants compared and contrasted these lessons with the one they experienced, and they discussed possible advantages of presenting information in the way it was delivered in the learning cycle lesson.

During the concept introduction phase, it was revealed to the participants that the lesson they had experienced was a learning cycle lesson. They were provided with information about why this instructional strategy is sound pedagogy, and they were provided with additional examples of learning cycle lessons that could be used at various K-8 grade levels.

The application phase consisted of having the participants apply the learning cycle to their respective classes. In small groups, they were asked to develop a science lesson that followed the learning cycle format. Each group was asked to share its lesson with its peers to obtain feedback. After this, each participant was asked to develop additional lessons that could be used with his/her classes. As part of the evaluation procedures of this program, the participants were asked to teach these lessons to their students and provide the inservice staff with information about how effective these lessons were in creating student interest and in developing concepts.

Phase I—Teacher CADRE

The inservice program was divided into three major components: (a) the formation of a teacher CADRE, (b) the development of a manual containing sample learning cycle lessons, and (c) the organization and delivery of four two-day science workshops throughout the State of Indiana (See Figure 2). During the first phase of this program, a CADRE of 21 K-8 teachers was selected (10 from a residential school for the deaf and 11 from the public schools) to attend a five-day summer workshop and two follow-up sessions during the next academic year. Each of the teachers chosen for this program had filed a formal application that asked them to explain why they wanted to participate in the inservice and how they felt this program would benefit them. Any certified K-8 teacher of hearing-impaired children in the State of Indiana was eligible for this program. Those teachers that were selected presented a strong rationale (as defined by the inservice team) for their need for inclusion in the teacher CADRE. The total CADRE was chosen from a pool of 20 residential teachers and about 100 public school personnel.

During the summer workshop, the CADRE teachers experienced learning cycle lessons and compared and contrasted these lessons with similar lessons that did not follow this approach (exploration phase). They were introduced to the mechanics and philosophy of the learning cycle, were provided with sample learning cycle lessons, and were introduced to ways to integrate science with other disciplines (concept introduction phase). In addition, they were given time to develop and share learning cycle lessons that they would use with their students during the next academic year (concept application phase).

Evaluation of Phase I

The summer workshop was followed by two post-workshop sessions during the fall and spring semesters of the next academic year (continued concept application). At each session, the CADRE teachers had the opportunity to share ways they had applied the ideas and information they gained from the summer workshop. Prior to each post-session, the teachers sent one lesson they had used with their students to the inservice staff. During the post-sessions the CADRE was also provided with feedback about the mechanics of their lessons. For

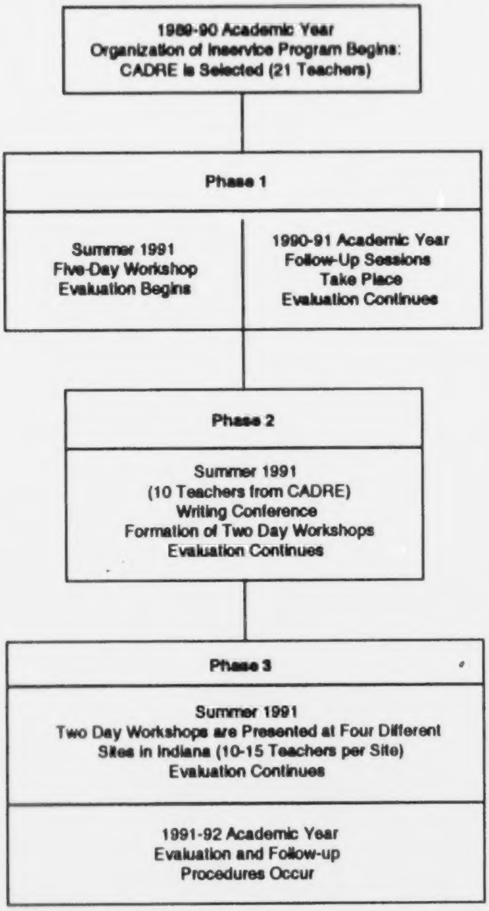

1989-90 Academic Year
Organization of Inservice Program Begins:
CADRE is Selected (21 Teachers)
Phase 1
Summer 1991
Five-Day Workshop
Evaluation Begins
1990-91 Academic Year
Follow-Up Sessions
Take Place
Evaluation Continues
Phase 2
Summer 1991
(10 Teachers from CADRE)
Writing Conference
Formation of Two Day Workshops
Evaluation Continues
Phase 3
Summer 1991
Two Day Workshops are Presented at Four Different
Sites in Indiana (10-15 Teachers per Site)
Evaluation Continues
1991-92 Academic Year
Evaluation and Follow-up
Procedures Occur

Figure 2. The inservice program

example, the lessons were evaluated on these criteria: (a) Did the lessons include all three phases of the learning cycle? (b) Were these phases in the proper sequence? (c) Was the main concept of the lesson developed as an outgrowth of the exploration phase and did the students have the opportunity to apply the concept to a new situation? Using these guidelines, 84% of the first set of lessons were considered to be good examples of learning cycle lessons, while 79% of the second set of lessons exemplified the learning cycle approach.

After the second follow-up session, the CADRE teachers were given an evaluation instrument to assess their perceptions about developing and implementing learning cycle lessons in their classes and to determine whether they believed their students had benefited from these lessons. This instrument was open-ended, allowing teachers to focus on their students' reactions to the learning cycle. The instrument also encouraged teachers to provide perceptions of themselves while using a learning cycle model. It was evident from the teachers' responses that they felt the learning cycle was an effective teaching strategy (Barman, Cohen, Furuness & Shedd, 1991). Several teachers agreed that the learning cycle had changed their philosophy of teaching. These teachers felt that the learning cycle allowed for more flexibility over the traditional textbook approach. For example, they believed it was easier to incorporate a variety of resources into their lessons using the learning cycle. Several teachers also noted they had used the learning cycle with other subject areas such as social studies, language arts, and mathematics. The teachers were also quite candid about the problems they faced in moving from a traditional textbook approach to the learning cycle. Several teachers indicated that this transition required a period of adjustment. As one teacher observed, "It takes at least one semester for a teacher and students to make the transition from textbook-bound lessons to the learning cycle approach."

In relation to student benefits, the CADRE teachers felt that the time they invested in adapting to the learning cycle was well spent. They reported that the learning cycle lessons helped their students become more responsible for their own learning. In addition, they felt the learning cycle increased student motivation and curiosity to learn and enhanced their students' ability to make observations and inferences, form predictions, and solve problems.

Phase II—Writing Conference

To implement the second phase of the inservice program, 10 teachers (at least one from each K-8 grade level) were selected from the CADRE of teachers established in phase one. These 10 teachers had demonstrated the ability to develop and to implement learning cycle lessons in the previous component of the inservice program.

The second phase began with a ten-day writing conference during the summer of 1991. The main goal of this component of the inservice program was to engage the 10 teachers in developing a manual containing information about the learning cycle and several examples of primary, upper elementary, and middle school science lessons that followed this approach. In addition to the development of the manual, an outline for future inservice workshops was constructed by the teachers and the inservice staff. At the end of the writing conference, a manual titled Doing Science Using the Learning Cycle (Barman, Barman & Cullison, 1991) was developed and the procedures for a two day workshop were identified.

Phase III—Two-Day Workshops

The third part of the inservice program began during the summer of 1991 and continued through the 1991-92 academic year. This part of the program consisted of presenting four two-day science workshops throughout the State of Indiana to a total of 36 teachers of the hearing-impaired who had not participated in the previous components of the inservice program. Each two-day workshop was conducted by several of the teachers who participated in the writing conference. The primary objectives of these workshops were to introduce teachers to the learning cycle, to provide them with a rationale for using this strategy, and to assist them in integrating this approach into their science curriculum.

As was done in the initial workshop, the format for these workshops modeled the learning cycle approach. For example, the teachers in these workshops were introduced to the learning cycle in a similar manner to the way the CADRE teachers were introduced to it. They experienced a lesson that followed the learning cycle format and were given time to compare and contrast this lesson with two other examples that did not follow the learning cycle (exploration phase). Next, they were provided with information about the mechanics and philosophy of the learning cycle and were shown several examples of learning cycle lessons (concept introduction phase). Finally, in small groups, they were asked to develop a science lesson that followed the learning cycle and share this lesson with other workshop participants to obtain feedback about it. The participants were also asked to develop additional learning cycle lessons that could be integrated into their science curriculum (application phase).

Evaluation of Phase III

At the end of each session, the workshop participants were given an evaluation instrument to determine their perceptions of the two-day workshops. As with the previous evaluation instrument, this instrument was open ended. However, this instrument focused on the workshop participants' ratings of the workshops rather than their perceptions of their roles in classrooms. Each of the four workshops were rated highly by the participants. They indicated that the workshops provided them with a good introduction to and a good understanding of the learning cycle, and provided them with a good resource book of lessons. The participants noted that they valued the manual, Doing Science Using the Learning Cycle, because it was written by teachers, and it included lessons actually taught by teachers. Furthermore, the participants indicated that the workshops were of value because they were taught by peers who were aware of the problems involved in teaching students with hearing impairments.

The workshop participants also were asked to conduct two follow-up activities during the 1991-92 fall and spring semesters. In the fall semester, they were asked to teach several lessons from the Doing Science Using the Learning Cycle manual and to provide the inservice staff with information about the effectiveness of these lessons. When they provided this information to the inservice staff, they were contacted by one of the leaders of their two-day workshop. The purpose of this contact was to provide support and to answer any questions related to the implementation of the learning cycle lessons. During the spring semester, each participant was asked to send the inservice staff one learning cycle lesson he or she had developed and to provide written comments describing their classroom experiences with this lesson. In addition, they were asked to indicate whether they felt their students had learned the concept(s) presented in the lesson. The teachers were provided with feedback about the mechanics of their lessons by one of the workshop leaders, and the leaders answered any questions the teachers had about the implementation of their lessons.

The information obtained from the participants' written comments about their classroom experiences with the learning cycle indicated positive feelings about the use of this approach. In comparing the students' reactions to learning cycle lessons versus the typical way they approached teaching science (primarily a reading exercise), all participants indicated that their students were more attentive, more involved, and more excited about the learning cycle lessons. The teachers perceived that their students had a better understanding of science concepts when taught with the learning cycle approach. In addition, the teachers noted the value of accessing prior knowledge during the exploration phase so they could adjust the lesson to the specific needs of their students.

In their comments, the participants also wrote about the perceived differences in their roles as "teacher" in the learning cycle lessons as compared with their typical presentation of a science lesson. While several participants admitted some difficulty in changing their behavior, most of them described their roles as being a facilitator. They felt more like a participant in the lesson, and they enjoyed their "new" role. They found that the development of learning cycle lessons did take more time and planning than their typical science lessons. However, several noted that the development of the learning cycle lessons was a more creative and challenging endeavor and was worth the effort.

The lessons that the workshop participants developed were evaluated by the project director to determine whether they followed the learning cycle format. The same criteria were used to evaluate these lessons as were used in Phase I (e.g. Did the lessons include all three phases of the learning cycle? Were these phases in the proper sequence? Was the main concept of the lesson developed as an outgrowth of the exploration phase and did the students have the opportunity to apply the concept to a new situation?) Only one of the 36 lessons was not rated as complete and a good example of the learning cycle, indicating that the majority of the workshop participants could demonstrate proficiency in developing learning cycle lessons for hearing-impaired children.

CONCLUSION

As indicated earlier in this chapter, the overall goal of this inservice program was to enhance the science teaching skills of teachers of the hearing-impaired in the State of Indiana. Specifically, the objectives of this program were to introduce teachers of hearing-impaired children to the learning cycle, to help them implement this strategy into their classroom instruction, and to provide them with a rationale for using this approach. The evaluation data obtained during this project suggests that this program was successful in meeting its overall goal and the first two of the three specific objectives. The majority of teachers who participated in this project demonstrated that they were able to design and implement learning cycle lessons in their classes. The written data received from these teachers expressed a very positive experience using the learning cycle, and many felt that their students enjoyed studying science more by using this strategy than they did with a textbook-oriented approach. The fact that these teachers were able to move from a textbook-oriented approach to one that encouraged student exploration and the use of science process skills appears to indicate that they had enhanced their science teaching skills. However, the evaluation results did not document whether the majority of the participants were able to explain why the learning cycle is a sound teaching strategy to use with hearing-impaired children and, therefore, did not allow any conclusions to be drawn related to the success of the third objective.

Some other outcomes of this project were observed but not documented in the evaluation data. The 10 teachers that were involved in the writing of the manual, Doing Science Using the Learning Cycle, and those who conducted the two-day workshops appeared to benefit greatly from these experiences. Through informal conversations with these individuals, it was apparent that they not only gained personal confidence from this project, but also had a feeling of professional growth. These 10 teachers could verbally defend why the lessons they developed for the manual were sound learning experiences. In addition, those that conducted the workshops were able to communicate to their peers why the learning cycle is good pedagogy. Although the formal evaluation data did not document whether the participants could explain a rationale for using the learning cycle, these informal observations indicate that at least 10 of the participants could articulate this information.

Finally, we believe that this inservice program was successful because its overall design, activities, and instruction were set within the structure of the learning cycle. Such a structure provided a strong vehicle to introduce teachers to the learning cycle and to assist them in implementing this strategy into their classes.

ACKNOWLEDGMENT

The three phases of this inservice program were funded by grants 89-COM-08 and 90-IND-01 from the Indiana Commission for Higher Education.

REFERENCES

Barman, C. (1990). An expanded view of the learning cycle: New ideas about an effective teaching strategy, *Council for Elementary Science International, Monograph #4*.

Barman, C., Cohen, M., Furuness, L., & Shedd, J. (1991). Integrating science into the K-8 curriculum of deaf children. Final Report Submitted to the Indiana Commission for Higher Education. (ERIC Document Reproduction Service, No. ED 343779.)

Barman, C., Barman, N., & Cullison, M. G. (Eds.). (1991). Doing science using the learning cycle. Indianapolis, IN: Indiana University School of Education.

Council on Education of the Deaf. (1972) Standards for the certification of the hear-impaired. Tucson, AZ: Author.

Indiana License Program for Hear-Impaired. (1990). Ball State University Undergraduate and Graduate Program Announcement. Muncie, IN: Ball State University.

Lang, H. G. (1984). The hearing-impaired student in the science classroom. (ERIC Document Reproduction Service No. ED 258801.)

Lang, H. G., & Propp, G. (1982). Science education for hearing-impaired students: State of the art. *American Annals of the Deaf, 127*, 860-869.

Lawson, A., & Renner, J. (1975). Piagetian theory and biology teaching. *American Biology Teacher, 50*, 266-278.

Moores, D. (1987). Educating the deaf: Psychology, principles, and practice (3rd ed.). Boston, MA: Houghton Mifflin and Co.

SCIS Teachers Handbook (1974). Regents University of California, Berkeley, CA.

Sunal, D. W., & Burch, D. (1982). School science programs for hearing-impaired students. *American Annals of the Deaf, 127*, 411-417.

Chapter 15

Scientific Work Experience Programs for Science Teachers: A Focus on Research-Related Internships

Sandra S. Gottfried
Christopher W. Brown
Paul S. Markovits
Jerilynn B. Changar

Over 80 scientific work experience programs are now in existence in the United States (Industry Initiatives for Science and Math Education [IISME], 1991), providing a powerful mechanism of inservice professional development for teachers. Scientific work experience programs are those in which teachers work within businesses, industries, or universities in a variety of roles. The introduction to this chapter provides an overview of scientific work experience programs using information provided by the directors of 25 such programs. This information was provided in response to requests for information sent to approximately 70 scientific work experience program directors. After the overview, which includes the history of scientific work experience programs, we present a model of the research-based scientific work experience program, which was developed from a composite of four research-based programs we conduct in the St. Louis metropolitan area. Finally, we present specific outcomes from the St. Louis research internships and implications for schools and businesses, which extend beyond the summer internship.

INTRODUCTION TO SCIENTIFIC WORK EXPERIENCE PROGRAMS

History

Scientific work experience programs were not spawned by a single report, task force, or group of persons. They have a multitude of roots. Among the 25 programs that responded to our requests for information, Brookhaven National Laboratory (BNL) in Brookhaven, New York, has the oldest program, with its beginnings in the late 1970s. Initially, BNL hired teachers as accelerator operators during the summer to replace persons going on vacation. The success of this venture for both the teachers and BNL led in 1983 to the development of a scientific work experience program in partnership with Polytechnic University, sponsored by the National Science Foundation (NSF). Today, Brookhaven is one of 27 facilities that participate in the U.S. Department of Energy (DOE), Teacher Research Associates (TRAC) program that provides summer research appointments at U.S. Department of Energy national laboratories, facilities, and energy technology centers across the United States.

Many other scientific work experience programs began in the mid-1980s from independent industry initiatives, reportedly in response to documents such as *A Nation at Risk: The Imperative for Education Reform* (National Commission on Excellence in Education, 1983). One of the first such initiatives was launched in 1985 by a consortium of San Francisco Bay Area companies and government laboratories in conjunction with the Lawrence Hall of Science. Today, the Industry Initiatives for Science and Math Education places almost 100 teachers each summer in industry and government laboratories. In addition, IISME received funding in 1988 to support replication efforts, which led to the formation of programs in five other states based on the IISME model.

In the early 1980s, the U.S. Department of Education also provided an impetus to the development of scientific work experience programs for teachers. It directed the formation of various committees to develop recommendations regarding sound educational programs in response to the deficiencies in primary and secondary level science, math, and technology education in our nation's schools (Commission on Precollege Education in Mathematics, Science, and Technology, 1982; Hurd, 1982; National Academy of Sciences, 1982; National Science Foundation and U.S. Department of Education, 1980). One committee formed under this directive was the Task Force on Precollege Science Education Programs of the Federation of American Societies for Experimental Biology (FASEB) Education Committee. Reports prepared by the FASEB Task Force (1983, 1984) emphasized that there was a lack of cooperation between the science education systems of secondary schools and universities. To address this concern, the FASEB Task Force studied ways in which research scientists might help upgrade primary and secondary science education. One suggestion made in both reports was that industrial and academic scientists provide opportunities for science teachers that included part-time employment in the research setting, summer research participation programs, and/or tours of research facilities. Although FASEB did not initiate any scientific work experience programs itself, various member societies of FASEB did. For example, the American Society for Biochemistry and Molecular Biology began a national scientific work experience program in 1984. The American Association of Immunologists also initiated such programs. Started in 1989, their St. Louis program is directed and coordinated by the Mathematics and Science Education Center at the University of Missouri-St. Louis. This program is incorporated into the St. Louis research internship model described later in this chapter.

Program Goals

Scientific work experience programs take place over six to ten-week periods in the summer with follow-up during the school year, although some have continuing work experiences spanning the school year or have academic experiences (such as courses or workshops) that extend beyond the summer. Many programs offer university credit for participation; some are a part of a master's degree program. All are considered internships because teachers work with mentors from the setting in which they are placed to do supervised work.

Most scientific work experience program directors report that a goal of their programs is to give teachers "real-world" experience. Project directors and developers want teachers to use this experience to: understand some of the kinds of skills scientists, engineers, and other types of technical workers need in the workplace; improve their technical/scientific knowledge base; and help students make career decisions. Many programs also suggest that a goal is to enhance the leadership skills of teachers. Additional goals of research-based internships are to develop an awareness and understanding of current science and technology and a better understanding of the nature of scientific research.

Types of Programs

In analyzing and synthesizing information from the respondents to our request for information, we found that scientific work experience programs can be grouped into three categories according to the type of scientific work teachers do: project internships, research internships, and a combination of both project and research internships. Listed in an appendix to this chapter are the names of programs and contact people grouped by category.

In project internships, teachers are placed within business or industry and complete a project for the company. Often, these are projects that the business could not get to with its available workforce. For example, a teacher may be asked to set up and test new equipment, write manuals, teach within the company, or modify computer programs. Occasionally a teacher will be assigned a research project or will be an observer rather than a worker. Primarily, however, teachers participating in these types of programs are given supervised projects to complete. To help teachers transfer their new knowledge, skills, and understanding to the classroom, project directors usually ask teachers to gather materials for classroom use (if any are available to them) and to compile lists of resource people. Sometimes teachers arrange joint school/sponsor activities during the summer. In addition, teachers are often asked to either develop a personal action plan for classroom transfer or analyze their summer experiences with respect to their implications for teaching. The largest of these types of internships responding to our request for information is the Academic Industrial Teachers Internship Program (AITIP) located in Madison, WI. AITIP has an engineering focus and places teachers with businesses, industries, and state agencies nationwide.

In research internships, teachers are placed in business, industry, or university settings and work with research scientists or engineers. Each teacher takes part in some aspect of the research work of his or her mentor. The research questions teachers explore vary tremendously and span both domains of basic and applied research. The U.S. Department of Energy Teacher Research Associates (TRAC) program is an umbrella for many of the research internship programs across the United States. Approximately 400 teachers participate annually.

In project/research internships, some teachers are placed in business, industry, or university research settings, while others are placed in business or industry with a project focus. The largest project/research internship program responding to our request for information is the Industry Initiatives for Science and Math Education (IISME) located in the San Francisco Bay area. IISME provides internships for approximately 100 teachers per year. In addition, IISME has helped launch over 20 other programs across the country based on the project/research internship model.

The predominant method of classroom transfer in both research internships and research/project internships is a curriculum development project. Through the development of their projects (a process often facilitated by a science educator) the teachers translate their summer experiences into instructional materials. In research or research/project internships not using this mechanism, teachers are often asked to submit a personal action plan of classroom transfer. This plan allows teachers a wide latitude to develop classroom and extracurricular activities they will carry out during the school year and encompasses topics such as teamwork, problem solving, communication skills, updating of content, and career awareness. A few programs have no structured mechanism of classroom transfer.

Evaluation/Outcomes

All respondents to our request for information evaluate their programs using qualitative methods. The types of evaluation tools used are teacher and mentor questionnaires, teacher interviews, and pre-to-post-program teacher and student attitude questionnaires. In the St. Louis research internship model we describe, quantitative measures of evaluation also are used.

An overwhelmingly consistent outcome reported by directors of all three types of scientific work experience programs is the increase in teachers' feelings of self-confidence, self-esteem, and professionalism. Scientific work experience programs are often catalysts, energizing teachers to aggressively pursue further professional development activities. These programs "recharge" teachers. After their summer experiences, most teachers are anxious to return to their roles in their classrooms, having reaffirmed their reasons for entering the teaching profession.

Another consistent outcome reported by directors is the realization on the part of teachers that communication skills as well as skills of cooperation and problem-solving are essential in the scientific/technological workplace. Following participation in scientific work experience programs, teachers report that they now plan lessons to develop these skills in their students and work toward increasing the use of cooperative learning strategies in their classrooms. Teachers also leave their internships with increased content knowledge regarding the project or research they completed and a clearer view of careers in science, technology, or engineering.

THE ST. LOUIS RESEARCH INTERNSHIP MODEL

Programs and Funding

The St. Louis research internship model is comprised of four programs that are philosophically and structurally similar. The first of these programs was conceived in 1987 with the first summer interns working in 1988. This program provided internships for teachers at the McDonnell Douglas Corporation (MDC) and was initiated by the Mathematics and Science Education Center (MSEC), a nonprofit professional development organization for mathematics and science teachers serving the St. Louis area. The MSEC is housed on the University of Missouri-St. Louis campus. The McDonnell Douglas Foundation and the McDonnell Douglas Corporation currently funds this eight-week program for five teachers at the McDonnell Douglas Corporation.

The MSEC has since developed two additional programs that provide internships at other sites in the St. Louis area. The American Association of Immunologists (AAI) funds a five-week program for four teachers at the Washington University and St. Louis University medical schools. This program began in 1990. In addition, the U.S. Food and Drug Administration (FDA) funds an eight-week program for two teachers at the FDA in St. Louis. This program began in 1992.

The fourth program making up the St. Louis research internship model is the Science Teachers as Research Scientists (STARS) program, initiated in 1990 by a faculty member at the University of Missouri-St. Louis (UMSL). The Missouri Coordinating Board for Higher Education funds this six-week program for five teachers at UMSL. The National Science Foundation funded a portion of this program in 1990 and 1991.

Although these four programs are conducted at a variety of sites and by a variety of people, a high level of interaction and communication takes place among key personnel to maintain a consistency of philosophy and create positive synergy. In addition, Civic Progress of St. Louis, a philanthropic organization composed of the CEO's of 24 major corporations and institutions in St. Louis, provides funding across programs, giving each teacher intern $200 for curriculum development materials or classroom laboratory supplies.

Goals

The decision was made at the outset that internships were to focus on professional development and help teachers understand the conditions and needs of industries and universities. Direct translation of the research experience to the classroom was considered a fundamental aspect of the experience. This desired structure translated into a program having three integral components: an internship experience, a curriculum project, and professional leadership opportunities. The goals of this tri-faceted approach are to: (a) provide teachers with experiences in science, mathematics, and technology in an industrial/

university research environment; (b) offer opportunities for teachers to interact with professionals from industry and academia in the fields of science, mathematics and technology; (c) assist teachers in translating what they learn during internship experiences into curriculum materials for use in the classroom; (d) encourage teachers to integrate a science-technology-society perspective with their math and science curricula; (e) reinforce the advantages of viewing curriculum development as an ongoing process that thrives on deliberation with colleagues; and (f) support teachers in their professional growth and development, encouraging them to share their experiences with colleagues to inspire them to pursue such professional development activities (Markovits & Mitchener, 1992).

Teacher Expectations

The internship application process, questionnaires, interviews, and weekly meetings provided us with information on the teachers' expectations. In general, teachers' reasons for applying for internships relate to becoming better teachers. More specifically, teachers expect to: (a) increase their knowledge of science, mathematics, computer science, and technology; (b) add to their laboratory experiences regarding techniques, procedures, knowledge of apparatus, and science process skills, (c) participate in research; (d) broaden their understanding of technology; and (e) learn about real-world "stuff" and workplace concepts for classroom applications.

The teachers' expectations are noteworthy not just for the information they provide for program planning and outcome assessment, but also for what they reveal about their interests, strengths, weaknesses, and openness to change. They are particularly revealing regarding the range and level of specificity of their implied outcomes. For example, the following selected comments reflect teachers' expectations at a personal level:

> I want to see how different the business world is compared to what happens in schools. What does it feel like to work 8:00 to 5:00 and walk away from the challenges until the next day?
>
> I want to see how scientists and engineers solve problems. What methods do they use? Can I learn these same strategies? A touch of the "real world" is probably good for teachers.
>
> I know I have much to learn, but I have this mortal fear that my mentor will be a former student–who could find out how little I really know!

Teachers' expectations at the classroom level are revealed in the following comments:

> I would like to develop a technology activity to use with students in meeting state objectives related to energy, power, and transportation.

> I want to find some new ways of bringing "real-world" applications to my classroom as a way of motivating students.
>
> I will be teaching physics and chemistry for the first time, so I will be looking for ideas I can use to integrate these two subjects on an advanced level.
>
> There are so many different people that work in research. I hope I can help inform and motivate students to seek a career in science.

The following comments reflect teachers' expectations at the district level:

> I hope the internship will help me improve what is being taught regarding computer science across the district. I would like to examine whether what is taught in mathematics should be revised to support the computer education program.
>
> I am very interested in implementing the new National Council of Teachers of Mathematics standards. Our district is planning a curriculum review, and I think my new knowledge will be valuable.

Finally, these comments show teachers' expectations at the national level:

> I'd like to send a message to my colleagues–we (teachers) should not build our own little worlds in our classrooms. Our classrooms should be a reflection of the real world, and it is our responsibility to find out what it is.
>
> I am excited about having the opportunity to be on the cutting edge of science and technology, and share this knowledge with colleagues across the country.

In a sense, teacher expectations begin to create the lens through which the teachers see the potential impact the internship will have on them, their classrooms, their district, and their collegial interactions both locally and nationally. A variety of factors affect the ability of any research internship to match the expectations of its teachers and achieve its goals. Important key components to each facet of the internship are described below, as well as other factors critical to program success.

The Internship Experience

The St. Louis research internships involve mathematics, science, computer science and industrial technology teachers; however, most participants are science teachers. Each teacher intern is assigned to a mentor or group of mentors in an active, investigative laboratory setting. They work within a corporate department or within an academic research setting and become involved in the research projects of their mentors. The expectations of what the teachers will accomplish within the research setting is determined by the length of the internship, the background of the teacher, and the complexity of the questions being researched and techniques being used. Within the scope of their internships, teachers may be expected to engage in such activities as participating in brainstorming sessions, conducting library research, performing experiments, preparing reports, and making presentations.

The mentors chosen to work with teachers have actively sought involvement in the program. Most mentors consider the internship an excellent opportunity to serve the education community and take part because they are interested in enhancing the education of teachers. With the exception of mentors in the university who receive a modest honorarium, mentors are not paid.

The Curriculum Project

The St. Louis research internships place a strong emphasis on curriculum development as a process leading to increased professional development of teachers. The curriculum component of the internship experience represents the teachers' first tries at processing their new knowledge, skills, and attitudes in a concrete fashion. In this regard, each teacher's curriculum project is viewed not as an end product of the internship but as an integral part of the process: the means by which new knowledge, skills, and attitudes become refined, extended, and internalized.

As a group, teacher interns are guided through the curriculum development process by a science/mathematics educator with expertise in curriculum development. Throughout the internship experience, specific times are set aside for collaborative work among the teachers and with the science/mathematics educator to discuss curriculum design as well as the internship experience. The activities they develop must be student-centered, hands-on, and challenging. The learning cycle strategy, a problem-solving approach, or another inquiry approach must be used as the basis for the development of the activities. Some programs stress that the concept of technology and its interrelationships with society should be an integral part of the lesson. The teachers develop their own lesson(s) because each is engaged in a different content area. However, they work collaboratively to critique one another's materials, pilot one another's activities, and share references and resources. The focuses of the projects are extremely varied and have included such topics as aerospace technology, antigen-antibody interactions, fiber optics, statistical analysis, artificial intelligence, and materials design.

Before curricular materials are used in the classroom, they are submitted to the curriculum coordinators in each teacher's school system for approval. After piloting, the lessons are revised for final publication by the Mathematics and Science Education Center. The development of activities, subsequent classroom implementation, and professional presentations to colleagues result in a well-developed sense of ownership, not only of the curriculum project, but also of the internship experience and all its facets. As teachers move through the process of translating their experiences into classroom applications, this curriculum development process becomes an effective teacher enhancement process, having implications far beyond the scope of a few classroom activities.

Professional Leadership Opportunities

A requirement of the internships is a commitment by each teacher's school district to provide an opportunity for the teacher to conduct an inservice workshop on the internship experience and curriculum development project. School district support for participation by teacher interns in these professional activities has been extremely positive. Teachers have been given time and financial support far beyond the requirements of the internship.

The McDonnell Douglas Foundation provides travel stipends for teachers to present their work at local, regional, and national professional meetings. They also present their work at an annual meeting at McDonnell Douglas Corporate International Headquarters. The American Association of Immunologists (AAI) provides funding for teacher interns to attend the annual meeting of the AAI. They not only attend immunology sessions but present a workshop at the meeting for local teachers. For many teacher interns, these presentations are their first at a regional or national conference.

Evaluation

Prior to the first summer of each program making up the St. Louis research internship model (the FDA, MDC, AAI, and STARS programs), formative evaluation procedures were designed. The purpose of the formative evaluation was to collect data about each program while it was still being developed and then use the data to modify the respective programs. In addition, the methods of evaluation were reviewed to develop the most appropriate means by which to evaluate the further development of each program.

Like most other scientific work experience programs, the St. Louis research internships use questionnaires and interviews as primary methods of evaluation. These types of evaluation measures were used to evaluate the programs and determine whether project goals had been accomplished. Other critical aspects of the programs were evaluated also, such as the value of the programs as perceived by the teachers and the researchers (mentors), and the manner in which the programs were structured.

The design of the evaluation differed across internship programs. Our purpose here is not to describe the evaluation design of each program, but to simply describe some of the measures we used and present some of the data we collected. These data provide "snapshots" of teacher and mentor attitudes and perceptions, and student perceptions of the classroom environments teachers create before and after participation in research internships.

A questionnaire was developed for the STARS program to determine the teachers' perceptions regarding the increase in their understandings and knowledge in content and pedagogy. This questionnaire was administered to university teacher interns (N = 12) on the last day of the program during the summers of 1990 and 1991. (Data for the 1992 STARS program are not included here.) The directions ask teachers to assess, on a Likert scale ranging from 1 (low) to 5 (high), the amount of experience in research design and experimentation they received (M = 3.9). In addition, teachers ranked their perceived increase in science content knowledge (M = 3.9), ability to perform science process skills (M = 3.3), understanding of applications of science in the workplace (M = 3.9), knowledge of teaching strategies and learning theory (M = 4.0), and ability to design appropriate activities for classroom use (M = 4.0). Teachers also had an opportunity to comment on each question they rated.

Another questionnaire was developed for the STARS program to determine the researchers' (mentors') perceptions regarding the accomplishment of the objectives of the program and to assess the level of involvement of the teachers in the summer research experience. This questionnaire was administered two weeks after the summer programs of 1990 and 1991. The directions ask researchers (N = 12) to assess the degree of enhancement of the teacher's knowledge base in the research area (M = 3.9), degree of teacher participation in the exploration of one or more research problems (M = 3.9), the level at which the teacher participated in the day-to-day activities of the laboratory (M = 3.6), the degree to which the teacher demonstrated laboratory techniques, understood research methods, and learned the operations of technical equipment (M = 3.6), and the experience of having a teacher in the lab (M = 4.5).

A third teacher questionnaire was developed for the STARS program and was administered to university teacher interns (N = 11) six months after the 1990 and 1991 summer experiences to evaluate these teachers' perceptions of the impact of the program on their teaching. (One teacher was unable to participate in part of the evaluation.) The directions asked teachers to assess the extent to which they: found their hands-on lab experiences helpful in developing new or revised experiences for their students (M = 4.1); shared their experiences with fellow teachers (M = 3.3); incorporated content knowledge learned during the internship into their curricula (M = 3.8); found the introduction/review of the learning cycle strategy helpful in their day-to-day lesson planning (M=3.9); increased their discussion, modeling, and/or integration of research process/methodologies into their curricula (M = 3.9); changed their teaching strategies as a result of their summer experiences (M = 3.8); and felt more confident as a science teacher as a result of their summer experiences (M = 4.3). Other questions on this questionnaire were designed to reflect the categories of items on the Science Classroom Activity Checklist, which is discussed later in this chapter. Regarding classroom practice, teachers perceive that the program impacts their role in the classroom (M = 3.8), the students' role in the classroom (M = 4.0), and the lab follow-up activities they conduct (M = 3.8), more than their use of textbooks and reference materials (M = 3.4), and their design and use of tests (M = 3.3).

The MDC programs of 1988-1991 were evaluated by means of individual structured interviews of the teachers. The 1988 and 1989 MDC teachers (1988, $\underline{N} = 5$; 1989, $\underline{N} = 5$) were interviewed prior to their internships and after they had returned to their classrooms and implemented their lessons. The 1990 and 1991 MDC teachers were interviewed individually at the end of the summer program and as a group after classroom implementation of the curriculum projects (1990, $\underline{N} = 9$; 1991, $\underline{N} = 6$). In addition, teachers in the 1990 and 1991 programs completed questionnaires that asked questions similar to those asked in the interviews. The interview questions focused on program goals and objectives, beginning with broad-based open-ended questions, and ending with narrower, more convergent questions. The focus was on perceived personal and professional benefits for the teacher interns, their students, their colleagues, and the educational community. This process allowed the evaluator to probe specific responses and allowed interviewees to elaborate more than on the questionnaires. The interview transcripts were analyzed for patterns of responses. The questionnaire data were found to be consistent with the interview data.

Synthesized data across programs (which includes teacher comments on questionnaires, Likert scale data, and interview data) reveal that teachers perceive that they (a) increased their content knowledge in science and technology, (b) received a somewhat substantial amount of experience in scientific research design and experimentation, (c) increased their understanding of what engineers and scientists do day-to-day, (d) made substantial gains in their knowledge of applications of science in the workplace, (e) increased their awareness of the relationship of math and science to technology and society, (f) renewed their excitement about teaching, and (g) enhanced their desire and ability to design and implement hands-on inquiry-oriented lessons in their classrooms.

Pre-to-post-program classroom observational data were collected on teacher interns in the 1990 and 1991 STARS programs. A graduate student in education visited one class of each teacher on two different occasions prior to the start of the internship and six months after the internship was over. (Funding restrictions precluded more visits.) An analysis of the field notes reveals no observable differences in the teaching strategies of teachers after participation in research internships.

Other evaluation measures were used as a means of triangulation of the data gathered to evaluate the STARS program. Lincoln and Guba (1985), define the technique of triangulation as the use of multiple and different sources and methods of data collection to improve the probability that findings and interpretations will be found credible. One measure was a pre-to-post-program questionnaire given to the teachers at the time of classroom observations. The questionnaire asked teachers to state the percentage of their classroom time that involved particular teaching strategies stated in a list. Teachers reported using the lecture method less and engaging students in laboratory activities and non-laboratory hands-on activities for a greater percentage of their classroom time after participation in the research internship.

To further investigate the ways in which teaching strategies changed or did not change after participation in the research internship, The Science Classroom Activity Checklist (Kochendorfer, 1967) was administered to the students in the observed class of each teacher participating in the STARS program during the summers of 1990 and 1991. The Science Classroom Activity Checklist is a 53-item instrument in which a student answers true or false to a descriptor regarding behaviors of the teacher, behaviors of the students, or the nature of the use of textbooks, tests, and other materials in the classroom. It has established content validity. The reliability coefficient obtained with the Horst formula is .96. This instrument was chosen because it provides student-reported data and includes items regarding teaching strategies and the role of laboratory and other hands-on activities in the classroom. The investigators were interested in assessing changes at the classroom level resulting from teachers observing scientists at work, developing new understandings regarding the hands-on nature of science, and developing curriculum materials based on these new understandings. The checklist was administered just prior to the classroom observations both before and after the research internship took place. The data show no significant differences in any of the above categories.

Teachers in the STARS program during 1990 and 1991 also were given The Test of Integrated Process Skills (TIPS) (Dillashaw & Okey, 1980) before the internship began and immediately following the internship. The science process skills tested in this instrument are those associated with planning, conducting, and interpreting results from investigations. Usually referred to as the integrated science processes, they include formulating hypotheses, operationally defining terms, controlling and manipulating variables, planning investigations, and interpreting data. The difference between the means of the pre-test and post-test scores were not statistically significant.

Discussion

Results from evaluations of the St. Louis internships and knowledge gleaned from descriptive material sent to us by directors of the programs listed in the appendix indicate that teachers make substantial gains in the affective domain, which are easily documented by means of teacher questionnaires and interviews. In this regard, the interview technique has proven to be a valuable tool. It provides anecdotal data, rich with description of teacher feelings, perceptions, and insights. In addition, its guided yet open-ended nature allows for collection of "unexpected" data. Data collected from teacher interviews are described more fully below under the heading, "Beyond the Internship–Realizing the Outcomes."

Regarding knowledge, the only testing that has been done concerns science process skills. Although teachers do not exhibit statistically significant gains in these types of skills, many teachers do well on the pre-test, suggesting a ceiling effect. In addition, the skills acquired by teachers in their internships may be narrow and specific to each internship, therefore difficult to measure with a "generic" instrument. Teacher questionnaires and interviews reveal that teachers perceive that they have made gains in content/technical knowledge.

Teachers also perceive that they teach in a more hands-on manner, incorporating their new knowledge and skills from their research internships, as a result of participating in an internship. But, we have not been able to document these changes by means of classroom observations or by student-reported data from the Science Classroom Activity Checklist.

In summary, regarding changes in teaching practice, teacher perceptions of change do not match with other measures of change. These data suggest that either (a) the methods we are using are not detecting changes that exist, or (b) that observable, measurable change is not taking place. Perhaps, if it were possible to extend pre- and post-observation periods until data saturation was reached, changes might be noted that are not apparent in two pre-program and two post-program observations. The data from teacher interviews and questionnaires suggest that some type of change is occurring in teacher practice. This change may involve the way in which a teacher views what she or he does; after the internship experience teachers appear to view their roles in their classrooms through different "lenses," which impacts their decision making in ways we have yet to measure. Researching changes in teacher decision making may be an interesting and fruitful area of research regarding teacher change as a result of participating in a research internship.

In designing studies regarding outcomes of scientific work experience programs, researchers must keep in mind their intended audience. If an audience is the funder of the program, such as a business or industry, they may find anecdotal information interesting and revealing, but may be more interested in a concise format that includes quantitative data. Businesses and industries may also be interested in evaluation data that not only demonstrate that the program is meeting the stated goals but that it is impacting the teachers, students, and schools in the community. We suggest the use of Likert-scale questionnaires in which data regarding the affective domain, teacher/mentor perceptions, and evaluation of programmatic issues can be easily researched and succinctly reported. Those persons interested in researching the effects of research internships on teacher change may elect to employ the other types of evaluation measures such as those described above.

BEYOND THE INTERNSHIP: REALIZING THE OUTCOMES

As mentioned previously, teacher questionnaires and interviews provide data rich with description regarding teacher attitudes and perceptions before, during, and after their internship experiences. These data reveal detailed information regarding teacher outcomes in four areas: (a) knowledge and skills, (b) professionalism and self-esteem, (c) curriculum and instruction, and (d) attitudes toward change. Outcomes in each of these areas will be described below. Figure 1 provides an overview of the relationships among these outcomes as reported by teachers.

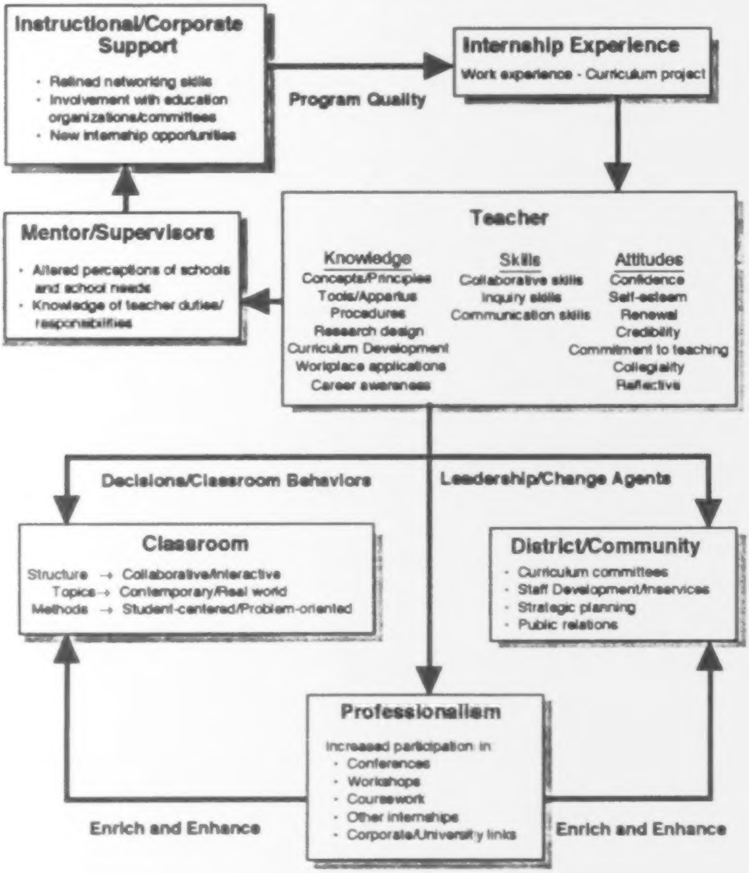

Instructional/Corporate Support
· Refined networking skills
· Involvement with education organizations/committees
· New internship opportunities
Program Quality
Internship Experience
Work experience - Curriculum project
Mentor/Supervisors
· Altered perceptions of schools and school needs
· Knowledge of teacher duties/ responsibilities
Teacher
Knowledge
Concepts/Principles
Tools/Appartus
Procedures
Research design
Curriculum Development
Workplace applications
Career awareness
Skills
Collaborative skills
Inquiry skills
Communication skills
Attitudes
Confidence
Self-esteem
Renewal
Credibility
Commitment to teaching
Collegiality
Reflective
Decisions/Classroom Behaviors
Leadership/Change Agents
Classroom
Structure → Collaborative/Interactive
Topics → Contemporary/Real world
Methods → Student-centered/Problem-oriented
District/Community
· Curriculum committees
· Staff Development/Inservices
· Strategic planning
· Public relations
Professionalism
Increased participation in:
· Conferences
· Workshops
· Coursework
· Other internships
· Corporate/University links
Enrich and Enhance
Enrich and Enhance

Figure 2. Research-Related Internships: Implications for Teacher Enhancement and Change

Teachers report a wide range of changes in their knowledge, skills, and attitudes as a result of their internships. In Figure 1, these changes are linked to the classroom, school district, and professional development by arrows that represent the implied effects associated with their experiences. After participating in research internships, teachers reveal greater efforts to transform their classrooms from one that isolates students to one that promotes collaboration and interaction. Teachers select topics for classroom activities that reflect "real-world" perspectives rather than provide discrete facts or bits of information to students. Their teaching strategies change from being teacher-centered to being student-centered with an emphasis on solving problems. In addition, many teachers report that their internship experiences have helped them become "change agents" in their respective schools and/or districts. They effect change by their work in curriculum development and staff development, and by linking the classroom with the community.

The internship model was designed to enhance teacher professionalism by providing opportunities for them to share their internship experiences and curriculum projects with colleagues at conferences and in workshops. A serendipitous effect is that teachers also share their reflections of the teaching experience with their mentors and supervisors, helping to educate them in ways that encourage their participation in educational organizations and heighten their interest in the internship program as well. As Figure 1 illustrates, it is becoming increasingly apparent that these shared experiences with both other teachers and with mentors are feeding back into the classroom and school district to enrich and enhance the change processes described earlier.

Knowledge and Skills

In all cases teachers report gains in their scientific or mathematical knowledge and skills. In addition, teacher interns frequently comment about the non-scientific knowledge and skills students would need if employed at the various host institutions. These "mega-skills" include teamwork, collaboration, networking skills, communication skills, and interpersonal skills. As one teacher intern states,

> I was under the impression that most scientists and engineers spent the bulk of their time in the lab doing "hands-on" kinds of things. I never realized how much writing they did. Information is constantly being researched, revised, and redistributed to others. The number of meetings they (scientists) have to attend to share ideas is amazing. They seem to have more time and opportunities than teachers for having "thinking conversations" about their work.

Professionalism and Self-Esteem

In addition to gaining knowledge, skills, and new perspectives about the workplace, teachers consistently describe a set of unexpected, intangible outcomes as a result of their internship experience. These intangibles represent a change in teachers' attitudes and have a significant effect on how teachers share/apply their new knowledge and skills with students and colleagues. One teacher comments,

> It just kind of renewed my basic feelings of the real world perspective. It was a kind of a renewal. It gave me a little more sense of purpose. . . . When I got to certain points in my curriculum, I find that I have a little more experience that I can draw upon to tell the kids and share with the kids.

Most teachers report an increased sense of collegiality and professionalism as a result of working with their research mentors and co-interns. They also report enjoying discussions with their mentors, which were stimulating and informational in a way that was atypical of school lunchrooms or staff lounge conversation. Teachers comment that the exchange of information is frequently a two-way process, with researchers learning a great deal from the teachers about life in schools and educational practices. As one teacher elaborates,

> Those were all off-the-cuff, across the desk, over the lunch table kind of discussions. I guess the most surprising thing was the day we were all talking about parent involvement in the schools. Many of them [the mentors] still thought that the only time you did that [talk to parents] was at parent conferences. And I guess what I was trying to say is there's more times that you can [involve parents]. . . . Some of their perceptions were that the schools are out there in a kind of vacuum.

A very real mutual respect develops between the teacher intern and researcher, which adds to the teacher's heightened self-esteem and confidence. One teacher reveals her feelings, stating that she learned, "I am just as capable in industry as I am in the classroom." Further, teachers benefit greatly from the positive reinforcement and empathy expressed by other professionals who realize that those who *can, do* teach.

On sharing their experiences and new workplace perspectives with students, teachers sense that students view them as credible professionals in ways they previously had not. Teachers describe their students as being genuinely interested in their experiences and eager to learn about happenings at the various corporations, universities, and research institutions. One teacher notes, "Many students are interested in the current research [in which I was involved] on the space plane, as well as [other] current research." Another teacher adds, "My students were aware of my internship at McDonnell Douglas and knew that the lesson was a result of the internship. They seemed to enjoy the lesson and felt that it was important."

Few teachers finish their internship experience believing that the grass is much greener on the other side. In fact, as previously mentioned, teachers return to classrooms with a renewed sense of enthusiasm. Although the teachers appreciate the level of intellectual interaction, challenge, and group problem solving, all feel that ultimately the classroom is the place for them and come away with a greater appreciation for teaching and the work they do with students. When asked by relatives if she were going back to the corporate world after her internship, one teacher responded, "No, teaching is what I love. This [the summer internship] is what makes it better."

Interestingly, industry mentors and supervisors gain a new understanding of teachers and teaching. This outcome serendipitously occurs as mentors, supervisors, and teacher interns informally discuss science education over lunch and during breaks. A teacher comments: "They were curious about my job. I mean, I got all kinds of questions about school—what kind of school I teach at, why is it so expensive, and why shouldn't someone consider private education over public." Another teacher comments: "One person was wondering how things had changed since they were in school. And we'd get into some of the problems that we have in education." The mentors and supervisors express that they had not been aware of teachers' many responsibilities and the variety of tasks teachers are expected to accomplish each day. Several have developed strong interest in the curriculum projects and their implementation. A few of the mentors have visited the schools to talk with students, and several more indicate they would be willing to visit the schools.

Curriculum and Instruction

Teachers generally feel that being a part of the "real world" is useful and provides an opportunity to make connections between classroom content and the world of work in a more reasonable fashion. Likewise, the internship helps reinforce some of the ideas and skills the teachers are currently teaching.

A significant impact on instruction occurs because internships place teachers back in learning-intensive roles. One teacher states: "I had much time to think, tinker with ideas, research, and discuss—just like 'real' scientists." In this regard, the internship brings teachers in contact with new people, new viewpoints, and new ways of looking at problems. Educational reforms in science and math challenge teachers to engage students in problem-solving, idea-sharing, and experimental design. Research internships place teachers in these same situations and provide a unique opportunity for teachers to reflect on the learning process; teachers have experiences that challenge them to rethink their own thinking and their own ability to solve problems.

Teachers definitely have renewed empathy for students after playing the role of students themselves. One teacher states she will no longer say, "Oh, it's easy," when a student is frustrated with a problem or unsure of directions. In addition, teachers plan to include new strategies to improve students' attitudes about math and science. One teacher plans to encourage female and minority students to get more involved in math and science classes.

Many teachers comment that they plan to guide their instruction away from teaching large amounts of facts and information. This represents a major shift in thinking for some. A mathematics teacher intern comments,

> In taking time to relate mathematics and problem-solving to the real world, I had to cover less material. I really felt

> uncomfortable with this. In the long run however, I feel my students were motivated to learn and had a better understanding of the concepts being studied. This may have actually saved me time.

A definite "less is more" attitude prevails among many of the teachers. Similarly, teachers mention the importance research and industry place on knowing how to learn versus simply knowing a specific set of facts. For this reason, concepts and skills associated with each curriculum project are placed in the context of a problem students must investigate or solve. Along with the incorporation of problem-solving and decision-making skills, all lessons develop fewer concepts in greater depth, promote interdisciplinary studies, balance content and process skills, stress cooperative learning strategies, relate to students' lives and their world, focus on broader goals that include societal perspectives and career awareness, and use alternatives to testing as assessment strategies.

For example, in one lesson, students learn about the kinetics of temperature change in structural materials by investigating problems related to developing materials that are lightweight yet durable enough to use in building a hypersonic space plane. Another lesson introduces students to aircraft design and performance analysis by presenting various flight scenarios and parameters, such as fuel, runway distance, and speed, which require the use of graphing or computer analysis. In another example, students learn about artificial intelligence through an analysis of logic statements, rules, and deductions needed to teach a computer to solve a problem.

The curriculum development process is a powerful tool that helps teachers operationalize the rethinking they do during their internships. Two chemistry teacher interns comment, "The curriculum development component was a vehicle for me to try more hands-on approaches to a chemistry lesson. It helped me rethink what should be taught and how to involve students in solving real-life problems," and "Through my curriculum project I began to realize the connection between the classroom and the workplace relative to career awareness, cooperative learning, and decision making."

An example of problem solving within a "real-life" context is illustrated by one chemistry teacher's lesson on composite materials. In this lesson, students design and test composite materials made from Styrofoam, fabric pieces, and glue. The concepts of strength to stiffness, stiffness to density, and cost to strength ratios are then extended as students design and test computer simulated skate boards, hockey sticks, tennis rackets, and other pieces of sporting goods equipment.

Weekly meetings provide teachers with immediate feedback and alternative viewpoints as they strive to translate their internship experiences into student experiences. From this process, a teacher emerges who is empowered with a broader view of his or her content area, a renewed empathy for student learning, and new strategies/methods for implementing instruction. The activities teachers develop based on their internship experience become important catalysts for change in the classroom. One math teacher reports that she rarely allowed students to do group work or move about in class because she was concerned about classroom management and disturbing neighboring classes. Her concerns were lessened considerably following a lesson in which students learned about the statistical concepts of central tendency and dispersion by throwing darts at a coordinate plane target to solve a problem about missile trajectory and targeting accuracy. She comments that the discussions, critical thinking, and genuine interest demonstrated by her students opened new possibilities for such lessons in the future. The view through the new "lens" teachers develop during and after internships and during the curriculum development process sharpens as teachers make decisions related to content, class structure, and instruction.

Classroom impact varies from reports of complete curriculum revisions to the discovery of new sources for field trips and guest speakers. The majority of teachers feel they are better prepared to share information about potential careers and the world of work. Teachers frequently discuss plans to offer students more hands-on opportunities, problem-solving activities, and open-ended questions. Further, teachers design lessons to include more collaboration among students to promote an exchange of ideas. Teachers' increased appreciation for communication skills prompts many to incorporate oral and written assessments in their lessons. One teacher intern has presented plans to his school to start a school journal for science. Another feels it is necessary to simplify terms and make sure his communication to students is clear, concise, and understandable.

Following the internship experience, many teachers feel that for the first time they understand the meaning behind the science-technology-society (STS) movement. Pre-internship questionnaires and interviews reveal almost as many definitions of technology and its relationship to science/math and society as there are teachers. Technology was often described as being synonymous with types of hardware or gadgets, such as CD-ROMs, computers, laboratory apparatus, and video equipment. Societal connections were almost always described in terms of applied science or math. Few teachers described STS as having a relationship to societal issues, problem solving, or career awareness. Post-internship interviews indicate that many teachers broadened their definitions of technology to include aspects of problem solving. In addition, teachers feel it is important to make scientists and engineers more available to students through classroom presentations or field trips and plan to make a greater effort to do so.

Implications for Teachers as Agents of Change

The shift in teacher attitudes relative to teaching/learning, the workplace, and professionalism has great potential for altering teachers' decisions regarding classroom practice, district policy, and professional standards. Most teachers would agree that they have far less impact on their school or school district than they have in their own classrooms. Nevertheless, most teachers believe that their internship experiences have helped them become "change agents" in their respective schools. Teacher impact within the school ranges from motivating colleagues to apply for similar internships to influencing the revision of entire school curricula in math or science. A computer science teacher states, "My internship helped broaden my understanding of computer science applications. I will need to examine whether what is taught in mathematics classes will need to be revised to keep pace."

Many teacher interns accept responsibility for motivating other teachers to get out of their regular niche and search out new ideas and projects for their students. One teacher intern comments, "It is important for me to convince my colleagues that science and technology are not 'people-eating monsters.'" Similarly, another teacher intern feels that by sharing his experiences through the university courses he teaches, he can motivate teachers to find stimulating summer experiences that will ultimately influence their own development and performance in the classroom.

Most teacher interns believe that direct, personal interactions with colleagues are the most effective ways to serve as change agents in their schools and school districts. Much of this interaction occurs in day-to-day conversations. Broader means of interaction and influence occur through curriculum committees, strategic planning committees, staff development programs, and program assessment committees. A mathematics teacher intern comments, "Our district is currently preparing to revise the entire mathematics curriculum. My internship experience has given me valuable knowledge to assist this process." Similarly, an industrial technology teacher intern now has the authority to guide a partial revision of the industrial education curriculum to include more technology application. The general consensus among teacher interns is that through their sharing of experiences, knowledge, skills, and attitudes gained through the internship, they have some influence on their colleagues that will ultimately assist them in becoming more informed and better teachers.

Teacher Professionalism: The "Endless Summer" Effect

The curriculum implementation and dissemination component of the project keeps the summer experience fresh and the potential for change alive for the teachers. Although the total extent of each teachers' internship and curriculum project responsibilities are clearly delineated at the outset of the summer, many interns reflect on the experience as having long-range effects on their careers as teachers. One teacher describes the internship experience as "a summer that never ends."

Post-internship discussions and follow-ups with many teachers reveal other aspects of professional development that are directly or indirectly associated with their involvement in the program. Some of these aspects include: (a) attending more professional conferences, (b) attending or providing after-school workshops, (c) taking additional coursework, (d) seeking other internships, (e) volunteering as mentors in school programs, and (f) establishing links with industry and research personnel. Teachers comment that some of their increased involvement is the result of motivation to act on new interests or heightened awareness of deficiencies in a particular area. For others, involvement has become a matter of professional standards and is expressed as a desire to assume a leadership role in facilitating change within their school or school districts.

Some teachers use their internship success as leverage in applying for similar, competitive programs and diverse educational opportunities that recruit teachers having the experience and leadership potential exhibited by the interns. Each teacher's additional professional development experiences ultimately feed back into the classroom, school, and school district to enhance and enrich science, technology, and mathematics education.

PERSONAL END NOTES

For those thinking about developing a research internship program, we have identified several key factors that lead to the effective implementation of a research internship program:

1. Clear, open, and frequent communication among the project director, science/math educator, mentors, and teachers is essential for project success.

2. Teachers who have an articulated project or research assignment, rather than a "shadowing" assignment, are more likely to realize fully the outcomes associated with a research internship that have been articulated in this chapter.

3. A curriculum component as a mechanism for classroom transfer and professional development is an effective professional development tool. This component should be facilitated by an expert in curriculum development who understands that the primary importance of the curriculum development project is the process in which teachers engage, rather than the products teachers produce.

4. Professional follow-through regarding implementation and dissemination of the curriculum project at local, national and regional levels further heightens teachers' professionalism and self-esteem.

5. Both quantitative and qualitative methods are useful in the evaluation of scientific work experience programs and together provide a clearer assessment than the use of only one of these methods. Teacher interviews are especially useful in revealing teacher feelings, perceptions, and insights and allow for the collection of unexpected data.

Despite the paucity of "hard" data regarding the effectiveness of research internships, we are convinced that research internships specifically and scientific work experience programs in general provide an outstanding model of teacher development. We infer from our data that research internships increase teachers' sense of professionalism, empowering them as change agents at a variety of levels. We also infer that by engaging in the scientific enterprise, teachers gain an understanding of the nature of the scientific process and infuse these understandings into their professional lives in ways we have yet to measure.

ACKNOWLEDGMENTS

The authors would like to thank Vicki May and Sheila Onuska for their constructive criticisms of our first draft, and Dana Benedicktus for her expertise and considerable time in copy editing and preparing this manuscript.

REFERENCES

Industry Initiatives for Science and Math Education. (1991). Sharing our successes: Changing the face of science & mathematics education through teacher-focused partnerships. Unpublished list of program profiles, University of California, Berkeley, Lawrence Hall of Science, Berkeley, CA.

Commission on Precollege Education in Mathematics, Science, and Technology. (1982). *Today's problems: Tomorrow's crises*. Washington, DC: National Science Board/National Science Foundation.

Dillashaw, F. G., & Okey, J. R. (1980, April). *A test of the integrated science process skills for secondary science students.* Paper presented at the National Association for Research in Science Teaching, Boston, MA.

Hurd, P. D. (1982, July). *Problems and issues in precollege science education in the United States.* Paper presented to the National Science Board Commission on Precollege Education in Mathematics, Science, & Technology, Washington, DC

Kochendorfer, L. H. (1967, October). The development of a student checklist to determine classroom teaching practices in high school biology. In A. E. Lee, (Ed.), *Research and curriculum development in science education: The new programs in high school biology.* (pp. 71-84). No. 6790. The University of Texas Publication (No. 6790).

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry.* Beverly Hills, CA: Sage Publications.

Markovits, P. S., & Mitchener, C. P. (1992). Technology in science and mathematics curriculum: An industry-university-school collaboration. In J. E. McEvoy (Ed.), *Partnerships in Chemical Research and Education* (pp. 80-86). Washington, DC: American Chemical Society.

National Academy of Sciences. (1982, May). *Science and mathematics in the schools: Report of a convocation.* Washington, DC: National Academy of Sciences

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: U.S. Department of Education.

National Science Foundation and U.S. Department of Education. (1980). *Science and engineering education for the 1980s and beyond.* Washington, DC: National Science Foundation and U.S. Department of Education.

Task Force on Precollege Science Education Programs. (1983). *Strategies for increasing involvement of research scientists in implementation of innovative science education programs: Phase I.* Bethesda, MD: Federation of American Societies for Experimental Biology.

Task Force on Precollege Science Education Programs. (1984). Strategies for increasing involvement of research scientists in implementation of innovative science education programs: Phase II. Bethesda, MD: Federation of American Societies for Experimental Biology.

APPENDIX: INTERNSHIP PROGRAMS FOR TEACHERS NATIONWIDE

Directors of the following internship programs responded to our request for information.

Project Internships

Academic/Industrial Teachers Internship Program (AITIP). Sponsored by Office of Engineering Minority Affairs; University of Wisconsin–Madison; 23 General Engineering Building 1527 University Ave.; Madison, WI 53706. Contact Alfred Hampton (608) 262-7764.

Distinguished Teachers Fellowship Program. Sponsored by Science Pioneers, Inc.; 425 Volker Blvd.; Kansas City, MO 64110. Contact Linda Segebrecht, President (816) 531-5124.

Recognize Exemplary Teachers–Expand, Enlist, Extend (RET–E^3). Sponsored by Grand Valley State University; 103 Loutit Hall; Allendale, MI 49401. Contact Mary Ann Sheline (616) 895-2265.

Research Internships

Alaska Summer Industrial Fellowships for Teachers (SIFT). Sponsored by Alaska Alliance for Science; 2231 S. Bragaw, Room 217; Anchorage, AK 99508. Contact Linda Okland (907) 263-7191.

American Society for Biochemistry and Molecular Biology Teacher Internships. Sponsored by American Society for Biochemistry and Molecular Biology; 9650 Rockville Pike; Bethesda, MD 20814. Contact Peter Farnham (301) 530-7147.

ASCI Science Teacher Summer Research Fellowship Awards. Sponsored by American Society for Clinical Investigation; 6900 Grove Rd.; Thorofare, NJ 08086. Contact Christine Malin (609) 848-1000.

Dutch Country Academic Alliance in Chemistry (DCAAC). Sponsored by Franklin & Marshall College Department of Chemistry; PO Box 3003; Lancaster, PA 17604. Contact Ronald Musselman (717) 291-4123.

Industry Fellows Program. Sponsored by San Diego County Office of Education; 6401 Linda Vista Rd.; San Diego, CA 92111. Contact Florine Belanger (619) 292-3850.

Philadelphia Science Resource Leaders for the Middle Grades. Sponsored by PATHS/PRISM; 7 Benjamin Franklin Parkway, Ste. 700; Philadelphia, PA 19103. Contact Emily Meyers (215) 665-1400.

Summer Research Program for High School Science Teachers. Sponsored by College of Physicians & Surgeons of Columbia University, Department of Physiology and Cellular Biophysics; 630 W 168th St.; New York, NY 10032. Contact Gail Cairns (212) 305-6899.

Elementary Teacher Research Internships. Sponsored by Pittsburgh Energy Technology Center; PO Box 10940; Pittsburgh, PA 15236. Contact Kee Rhee (412) 892-5913.

United States Department of Energy Teacher Research Associates (TRAC) Program. Information: John Ortman; Office of University and Science Education Programs; U.S. Department of Energy; ER 80, MS 3F-061/FORS; Washington, DC 20585.

Applications: Joan Miller (801) 278-0799; Associated Western Universities, Inc.; Attn: DOE/TRAC Program; 4190 S. Highland Dr., Ste. 211; Salt Lake City, UT 84124.

Sites: Los Alamos National Laboratory; Los Alamos, NM 87545. Contact Catherine Cottingame (505) 667-1919. Continuous Electron Beam Accelerator Facility (CEBAF); 12000 Jefferson Avenue Newport News, VA 23606. Contact Kathryn Strozak (804) 249-7100. Fermi National Accelerator Laboratory (Fermilab); MS 226, PO Box 500; Batavia, IL 60510. Contact Kristin Ciesemier (708) 840-3092.

United States Department of Energy (DOE) Science Teachers Research Involvement for Vital Education (STRIVE). Information: Science/Engineering Education Division; Oak Ridge Associated Universities; PO Box 117; Oak Ridge, TN 37831; (615) 576-2310.

Sites: Continuous Electron Beam Accelerator Facility (CEBAF); 12000 Jefferson Avenue; Newport News, VA 23606. Contact Kathryn Strozak (804) 249-7100. The University of Georgia Savannah River Ecology Laboratory; Drawer E; Aiken, SC 29802. Contact Teresa Carroll (803) 725-2472 (site serves both STRIVE and TRAC participants).

Project/Research Internships

CBIA Fellowship Program for Distinguished Teachers. Sponsored by Connecticut Business and Industry Association; 370 Asylum St.; Hartford, CT 06103. Contact Alison Burner (203) 244-1900.

Cleveland's Teacher Internship Program. Sponsored by Cleveland's Teacher Internship Program; 32000 Chagrin Blvd.; Cleveland, OH 44124. Contact Joseph Chadbourne (216) 464-1775.

Colorado Alliance for Science Summer Fellowship Program. Sponsored by Colorado Alliance for Science; Campus Box 456; University of Colorado at Boulder; Boulder, CO 80309. Contact Sharon Rogoff (303) 492-6392.

Ford Fellows Science/Mathematics Project. Sponsored by University of Washington; College of Education; Curriculum and Instruction; 122 Miller Hall, DQ-12; Seattle, WA 98195. Contact Carole Kubota (206) 543-8439.

Industry Initiatives for Science and Math Education (IISME). Sponsored by the Lawrence Hall of Science; University of California-Berkeley. Contact Marie Earl (408) 496-5340 c/o Deskin Research Group; 2270 Agnew Road; Santa Clara, CA 95054.

Laboratory Equipment Assistance Program (LEAP). Sponsored by Cansius College; Department of Chemistry; 2001 Main St.; Buffalo, NY 14208. Contact Janet Leone (716) 888-2340.

Partners for Terrific Science. Sponsored by Miami University; Terrific Science Programs; Middletown Campus; 4200 East University Blvd.; Middletown, OH 45042. Contact Lisa Meeder (513) 424-4444.

St. Louis Research Internships

The authors conduct the following internship projects in the St. Louis area.

American Association of Immunologists Teacher Internships. Sponsored by Mathematics and Science Education Center; 246 Benton Hall; 8001 Natural Bridge Road; St. Louis, MO 63121. Contact Paul Markovits (314) 553-5650.

Food and Drug Administration Technology in Context Teacher Internships. Sponsored by Mathematics and Science Education Center. Contact Paul Markovits (314) 553-5650.

McDonnell Douglas Technology In Context Teacher Internships. Sponsored by Mathematics and Science Education Center. Contact Paul Markovits (314) 553-5650.

Science Teachers as Research Scientists (STARS) Teacher Internships. Sponsored by University of Missouri–St. Louis Departments of Biology, Chemistry, and Physics; 8001 Natural Bridge Road; St. Louis, MO 63121. Contact Sandra Gottfried (314) 553-6542.

A Brief Guide to ERIC

The Educational Resources Information Center

Office of Educational Research and Improvement
U.S. Department of Education

What is ERIC?

The Educational Resources Information Center (ERIC) is a national education information network designed to provide users with ready access to an extensive body of education-related literature. Established in 1966, ERIC is supported by the U.S. Department of Education, Office of Educational Research and Improvement.

The ERIC database, the world's largest source of education information, contains over 735,000 abstracts of documents and journal articles on education research and practice. This information is available at more than 2,800 libraries and other locations worldwide.

You can access the ERIC database by using the print indexes *Resources in Education* and *Current Index to Journals in Education*, online search services, or CD-ROM at many libraries and information centers. The database is updated monthly (quarterly on CD-ROM).

The ERIC System

The ERIC System, through its 16 subject-specific Clearinghouses, 4 Adjunct Clearinghouses, and four support components, provides a variety of services and products that can help you stay up to date on a broad range of education-related issues. Products include research summaries, publications on topics of high interest, newsletters, and bibliographies. ERIC system services include computer search services, reference and referral services, and document reproduction. ACCESS ERIC, with its toll-free number, 1-800-LET-ERIC, informs callers of the services and products offered by ERIC components and other education information service providers.

ERIC Reference and Referral Services

With the world's largest educational database as a resource, ERIC staff can help you find answers to education-related questions, refer you to appropriate information sources, and provide relevant publications. ERIC components answer more than 100,000 inquiries each year. Questions should be directed to ACCESS ERIC or a specific Clearinghouse.

Specific documents: Requests for documents in the ERIC database for which you have an accession number (ED number) should be referred to an information provider near you. Call ACCESS ERIC to locate the nearest ERIC education information provider.

Subject-specific topics: Subject-related questions should be directed to the particular ERIC Clearinghouse whose scope is most closely associated with the subject matter involved. Or, call ACCESS ERIC for a referral.

Computer searches: Requests for a computer search should be directed to one of the search services listed in the *Directory of ERIC Information Service Providers,* available from ACCESS ERIC.

ERIC Clearinghouse publications: Requests for a publication produced by an ERIC Clearinghouse should be directed to the specific Clearinghouse.

Major ERIC Products

ERIC produces many products to help you access and use the information in the ERIC database:

Abstract Journals: ERIC produces two monthly abstract journals. *Resources in Education* (RIE), a publication announcing recent education-related documents, and the *Current Index to Journals in Education* (CIJE), a periodical announcing education-related journal articles, is available through Oryx Press (1-800-457-6799). Many libraries and information centers subscribe to both monthly journals.

***All About ERIC*:** This guide provides detailed information on ERIC, its products and services, and how to use them. Free copies are available from ACCESS ERIC.

***Catalog of ERIC Clearinghouse Publications*:** The *Catalog* lists publications produced by the ERIC Clearinghouses and support components, prices, and ordering information. Free copies of the *Catalog* are available from ACCESS ERIC.

***The ERIC Review*:** This journal discusses important ERIC and education-related developments. For a copy, call ACCESS ERIC.

Information Analysis Products: ERIC Clearinghouses produce reports, interpretive summaries, syntheses, digests, and other publications, many free or for a minimal fee. Contact the Clearinghouse most closely associated with your interests for its publications list. Call ACCESS ERIC for a free copy of the *Catalog of ERIC Clearinghouse Publications.*

Microfiche: The full text of most ERIC documents is available on microfiche. Individual documents and back collections on microfiche are available. Call the ERIC Reproduction Document Service (EDRS) for more information.

Thesaurus of ERIC Descriptors - The complete list of index terms used by the ERIC System, with a complete cross-reference structure and rotated and hierarchical displays, is available from Oryx Press.

ERICTAPES - Computer tapes of the ERIC database are available by subscription or on demand from the ERIC Facility (write for a price list).

ERIC Document Delivery

Documents: EDRS is the primary source for obtaining microfiche or paper copies of materials from the ERIC database. EDRS can provide full-text copies of most documents announced in Resources in Education (RIE), and ERIC's microfiche collection is available by monthly subscription from EDRS. EDRS also sells microfiche and paper copies of individual documents on request. For more information, call EDRS at (800) 443-ERIC.

Journal Articles: Two agencies that provide reprint services of most journal articles announced in *Current Index to Journals in Education* (CIJE) are listed below. Some journals do not permit reprints; consult your local university or local library to locate a journal issue. Or, write directly to the publisher. Addresses are listed in the front of each CIJE.

University Microfilms International (UMI)
Article Clearinghouse
300 North Zeeb Road
Ann Arbor, MI 48106
Telephone: (800) 732-0616

Institute for Scientific Information (ISI)
Genuine Article Service
3501 Market Street
Philadelphia, PA 19104
Telephone: (800) 523-1850

ERIC Information Retrieval Services

The ERIC database is one of the most widely used bibliographic databases in the world. Last year, users from 90 different countries performed nearly half a million searches of the database. The ERIC database currently can be searched via four major online and CD-ROM vendors (listed below). Anyone wishing to search ERIC online needs a computer or terminal that can link by telephone to the vendor's computer, communications software, and an account with one or more vendors.

The *Directory of ERIC Information Providers* lists the address, telephone number, and ERIC collection status for more than 900 agencies that perform searches. To order a copy, call ACCESS ERIC (1-800-LET-ERIC).

Online Vendors

BRS Information Technologies
8000 Westpark Drive
McLean, VA 22102
Telephone: (703) 442-0900
(800) 289-4277

Dialog Information Services
3460 Hillview Avenue
Palo Alto, CA 94304
Telephone: (415) 858-2700
(800) 334-2564

OCLC (Online Computer Library Center, Inc.)
6565 Frantz Road
Dublin, OH 43017-0702
Telephone (614) 764-6000
(800) 848-5878
(Ext. 6287)

CD-ROM Vendors

Dialog Information Services (same address as above)

Silver Platter Information Services
One Newton Executive Park
Newton Lower Falls, MA 02162-1449
Telephone: (617) 969-2332
(800) 343-0064

ERIC Components

Federal Sponsor

Educational Resources Information Center (ERIC)
U.S. Department of Education
Office of Educational Research and Improvement (OERI)
555 New Jersey Avenue N.W.
Washington, DC 20208-5720
Telephone: (202) 219-2289
Fax: (202) 219-1817

Clearinghouses

Adult, Career, and Vocational Education
The Ohio State University
1900 Kenny Road
Columbus, OH 43210-1090
Telephone: (614) 292-4353; (800) 848-4815
Fax (614) 292-1260

Counseling and Personnel Services
University of Michigan
School of Education, Room 2108
610 East University Street
Ann Arbor, MI 48109-1259
Telephone: (313) 764-9492
Fax: (313) 747-2425

Educational Management
University of Oregon
1787 Agate Street
Eugene, OR 97403-5207
Telephone: (503) 346-5043
Fax: (503) 346-5890

Elementary and Early Childhood Education
University of Illinois
College of Education
805 W. Pennsylvania
Urbana, IL 61801-4897
Telephone: (217) 333-1386
Fax (217) 333-5847

Handicapped and Gifted Children
Council for Exceptional Children
1920 Association Drive
Reston, VA 22091-1589
Telephone: (703) 620-3660
Fax: (703) 264-9494

Higher Education
The George Washington University
One Dupont Circle N.W., Suite 630
Washington, DC 20036-1183
Telephone: (202) 296-2597
Fax: (202) 296-8379

Information Resources
Syracuse University
Huntington Hall, Room 030
Syracuse, NY 13244-2340
Telephone: (315) 443-3640
Fax: (315) 443-5732

Junior Colleges
University of California at Los Angeles (UCLA)
Math-Sciences Building, Room 8118
405 Hilgard Avenue
Los Angeles, CA 90024-1564
Telephone: (213) 825-3931
Fax: (213) 206-8095

Languages and Linguistics*
Center for Applied Linguistics
1118 22nd Street N.W.
Washington, DC 20037-0037
Telephone: (202) 429-9551 and (202) 429-9292
Fax: (202) 429-9766 and (202) 659-5641
**Includes Adjunct ERIC Clearinghouse on Literacy Education for Limited English Proficient Adults*

Reading and Communication Skills
Indiana University
Smith Research Center, Suite 150
2805 East 10th Street
Bloomington, IN 47408-2698
Telephone: (812) 855-5847
Fax: (812) 855-7901

Rural Education and Small Schools
Appalachia Educational Laboratory
1031 Quarrier Street
P.O. Box 1348
Charleston, WV 25325-1348
Telephone: (800) 624-9120 (outside WV)
(800) 344-6646 (inside WV)
(304) 347-0400 (Charleston area)
Fax: (304) 347-0487

Science, Mathematics, and Environmental Education
The Ohio State University
1200 Chambers Road, Room 310
Columbus, OH 43212-1792
Telephone: (614) 292-6717
Fax (614) 292-0263

Social Studies/Social Studies Education**
Indiana University
Social Studies Development Center
2805 East 10th Street, Suite 120
Bloomington, IN 47408-2373
Telephone: (812) 855-3838
Fax: (812) 855-7901

***Includes Adjunct ERIC Clearinghouse on Art Education; and the National Clearinghouse for U. S.-Japan Studies*

Teacher Education
American Association of Colleges for Teacher Education (AACTE)
One Dupont Circle N.W., Suite 610
Washington, DC 20036-2412
Telephone: (202) 293-2450
Fax: (202) 457-8095

Tests, Measurement, and Evaluation
American Institutes for Research (AIR)
Washington Research Center
3333 K Street N.W.
Washington, DC 20007-3893
Telephone: (202) 342-5060
Fax: (202) 342-5033

Urban Education
Teachers College, Columbia University
Institute for Urban and Minority Education
Main Hall, Room 300, Box 40
525 West 120th Street
New York, NY 10027-9998
Telephone: (212) 678-3433; Fax (212) 678-4048

Adjunct Clearinghouses

National Clearinghouse on Literacy Education
Center for Applied Linguistics
1118 22nd Street N.W.
Washington, DC 20037
Telephone: (202) 429-9292
Fax: (202) 659-5641

Adjunct ERIC Clearinghouse for Art Education
Indiana University
Social Studies Development Center
2805 East 10th Street, Suite 120
Bloomington, IN 47405-2698
Telephone: (812) 855-3838
Fax: (812) 855-7901

National Clearinghouse for U. S.-Studies
Indiana University
Social Studies Development Center
2805 East 10th Street, Suite 120
Bloomington, IN 47408-2698
Fax: (812) 855-7901

Adjunct ERIC Clearinghouse on Chapter 1
Chapter 1 Technical Assistance Center
PRC, Inc.
2601 Fortune Circle East
One Park Fletcher Building, Suite 300-A
Indianapolis, IN 46241
Telephone: (317) 244-8160, (800) 456-2380
Fax: (317) 244-7386

Support Components

ACCESS ERIC
Aspen Systems Corporation
1600 Research Boulevard
Rockville, MD 20850-3166
Telephone: (800) LET-ERIC
Fax: (301) 251-5212

ERIC Document Reproduction Service
7420 Fullerton Road, Suite 110
Springfield, VA 22153-2852
Telephone: (301) 258-5500; (800) 443-ERIC
Fax: (301) 948-3695

Oryx Press
4041 North Central Ave., Suite 700
Phoenix, AZ 85012-3399
Telephone: (602) 265-2651; (800) 279-ORYX
Fax: (602) 265-6250; (800) 279-4663

How to Submit Documents to ERIC

ERIC collects a variety of materials on education-related topics. Examples of materials included in the database:

Research reports
Instructional materials
Monographs
Teaching Guides
Speeches and presentations
Manuals and handbooks
Opinion papers

Submissions can be sent to the Acquisitions Department of the ERIC Clearinghouse most closely related to the subject of the paper submitted, or sent to the ERIC Processing Facility.

NOTES

ERIC®

ERIC/CSMEE

1200 Chambers Rd., Rm 300 Columbus, OH 43212